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Rapidity and Accuracy Make for Efficiency.

A ROLLER GAGING MACHINE.—[See page 387.]

The Formation of Leafmold*

An Important Factor in the Production of Humus

By Frederick V. Colville

When the leaves of a tree fall to the ground they begin to decay and ultimately they are disintegrated and their substance becomes incorporated with the other elements of the soil. The same thing happens with the leaves, stems, and roots of herbaceous plants. Such organic matter is one of the chief sources of food for plants, and its presence in the soil is therefore of fundamental importance in the maintenance of the vegetative mantle of the earth.

In a series of experiments from 1906 to 1910 the speaker showed that a condition of acidity is a primary requirement of the blueberry, laurel, trailing arbutus, and other plants associated with them in natural distribution. Other kinds of plants and plant associations require on the contrary a neutral or alkaline soil.

It is the purpose of the present address to show how the leaves of trees in the process of the formation of leafmold produce at one time or under one set of circumstances a condition of soil acidity, at another time or under other circumstances a condition of alkalinity, and since the acidity of the soil is a fundmental factor in plant ecology, to point out that a knowledge of certain phenomena in the decay of leaves is essential to a correct understanding of the distribution of vegetation over the surface of the earth and its adaptation to the uses of man.

In the early experiments with blueberries it had been found that these plants grew successfully in certain acid soils composed chiefly of partially rotted oak leaves. On the rather natural assumption that the more thorough the decomposition of this material the more luxuriant would be the growth of the blueberry plant, some old oak leafmold, was secured for further experiments. It had been rotting for about five years and all evidences of leaf structure had disappeared. It had become a black mellow vegetal mold.

When blueberry plants were placed in mixtures containing this mold they did not respond with luxuriant growth. On the contrary their leaves turned purple and afterward yellowish, their growth dwindled to almost nothing, and at the end of the season when compared with other blueberry plants grown in a soil mixture in which the oak leafmold was replaced by only partially decomposed oak leaves the plants in the oak leafmold were found to weigh only one fifth as much as the others. This astonishing result is exactly contrary to the ordinary conception. We have been accustomed to believe that the more thoroughly decomposed the organic matter of a soil the more luxuriant its vegetation. In this case, however, thorough decomposition of the soil was exceedingly injurious to the plants.

This remarkable difference in effect between partially decomposed and thoroughly decomposed oak leaves was found to be correlated with a difference in the chemical reaction of the two materials, the partially decomposed oak leaves being acid, when tested with phenolphthalein, and the oak leafmold alkaline.

With rose cuttings and alfalfa seedlings in the same two soils exactly opposite results followed, those in the oak leafmold making a luxuriant growth, those in the partially decomposed oak leaves showing every sign of starvation.

Every botanist is familiar with the rich woods where trillium, spring beauty, mertensia, and bloodroot delight to grow, in a black mellow mold made up chiefly of rotted leaves. He is familiar too with the sandy pine and oak woods where grow huckleberries, laurel, princess pine, the pink lady's slipper, and trailing arbutus. The soil here also is made up chiefly of rotting leaves and roots. Yet one does not look for trilliums in laurel thickets, or for arbutus among the bloodroots. Either habitat is utterly repugnant to the plants of the other.

Tests of the two habitats show that the trillium soil is alkaline, the other acid, reactions corresponding exactly to those observed in the cultural experiments already described, rose cuttings and alfalfa requiring an alkaline soil, blueberries an acid soil. The difference is as conspicuous in nature as in the laboratory and the greenhouse. What are the conditions under which rotting leaves develop these opposite chemical reactions?

In a ravine in the Arlington National Cemetery, near Washington, where the autumn leaf fall from an oak grove has been dumped year after year for many years, every stage in the decomposition of oak leaves may be observed, from the first softening of the dry brown leaf by rain to the black mellow leafmold in which all traces of leaf structure have disappeared. When freshly fallen the leaves show 0.4 normal acidity.[1] Those not familiar with the chemical expression "normal acidity" may perhaps most readily understand the term by reference to ordinary lemon juice, which has very nearly normal acidity in the chemical sense. Fresh oak leaves may be conceived therefore as having about one third the acidity of lemon juice, gramme to cubic centimeter. From a soil standpoint such a degree of acidity is exceedingly high. Probably no tree or flowering plant could live if its roots were imbedded in a soil as acid as this. A correct appreciation of the excessive acidity of freshly fallen leaves enables one to understand why it is that the leaves of our our lawn trees, if allowed to lie and leach upon the grass, either injure or destroy it. On such neglected lawns the turf grows thin, mossy, and starved.

From the height of their initial acidity it is a long descending course through the various stages of leaf decomposition to the point of chemical neutrality, and then upward a lesser distance on the hill of alkalinity, in the black leafmold stage.

In order to ascertain the rate of decomposition in leaves of various kinds, observations were begun in the autumn of 1909 on leaves of silver maple, sugar maple, red oak, and Virginia pine, exposed to the weather in barrels and in concrete pits. In one experiment a mass of trodden silver maple leaves 2 feet in depth, with an initial acidity of 0.92 normal, was reduced in a single year to a 3-inch layer of black mold containing only a few fragments of leaf skeletons and giving an alkaline reaction. In these experiments sugar maple leaves have shown a slower rate of decomposition than those of silver maple, while red oak leaves still show an acidity of 0.010 normal after three years of exposure, and leaves of Virginia pine an acidity of 0.055 normal under the same conditions.

The alkalinity of leafmold is due chiefly to the lime it contains, the lime content expressed in terms of calcium oxid often reached 2 to 3 per cent of the dry weight. One sample had a lime content of 3.55 per cent. Many of the soils that result directly and exclusively from the decomposition of limestone have a lower percentage of lime than this. An alkaline leafmold containing 2 to 3 per cent of lime is properly regarded as a highly calcareous soil. Yet such a deposit may be formed in a region where the underlying soil is distinctly noncalcareous, the lime content of the soil being only a small fraction of 1 per cent and the soil reaction being acid. Whence comes the abundance of lime in an alkaline, richly calcareous leafmold formed over a soil distinguished by an actual poverty of calcareous matter?

If the leafmold is rich in lime the leaves from which it is derived should also be rich in lime. A determination of the amount of calcium oxid in the dried freshly fallen leaves of some of our well known trees shows this to be true, as illustrated by the following selections:

Kind of leaves.	Per cent of calcium oxid.
Red oak (*Quercus rubra*)	1.73
Silver maple (*Acer saccharinum*)	1.88
Pin oak (*Quercus palustris*)	1.91
Sweet gum (*Liquidambar styraciflua*)	1.92
Bur oak (*Quercus macrocarpa*)	2.39
Sugar maple (*Acer saccharum*)	2.56
Tulip tree (*Liriodendron tulipifera*)	2.84
Hickory (*Hicoria myristicaeformis*)	3.66
Gingko (*Ginkgo biloba*)	4.38

It should be understood that the line thus shown does not exist in the leaf in the form of actual calcium oxid. It is largely combined with the acids of the leaf and serves in part to neutralize them, but is insufficient in amount to effect a complete neutralization. In all the kinds of leaves and herbage thus far examined, the net result is an acid condition although lime may be present in large amount. Thus in the leaves of silver maple a condition of excessive acidity exists, about 0.9 normal, notwithstanding the presence of nearly 2 per cent of lime.

As the decomposition of such leaves progresses the acid substances are disorganized and largely dissipated in the form of gases and liquids, while the lime being only slightly soluble remains with the residue of decomposition, the black leafmold, and renders it alkaline.

In soils poor in lime, trees and other plants constituting the vegetative mantle of the earth may be regarded as machines for concentrating lime at the surface of the ground. This lime is drawn up by the roots in dilute solution from lower depths, is concentrated in the foliage, and the concentrate is transferred to the ground by the fall and decomposition of the leaves. The proverbial agricultural fertility of the virgin timberlands of our country was undoubtedly due in large part to the line accumulated on the forest floor by the trees in preceding centuries, and to the consequent alkalinity of such surface soils when the timber had been removed and the leaf litter was thoroughly decomposed. After a generation or two of reckless removal of crops the surface accumulation of lime was depleted and unless the underlying soil was naturally calcareous a condition of infertility ensued which for the purposes of ordinary agriculture could be remedied only by the artificial application of lime.

The chief agents in the decay of leaves are undoubtedly fungi and bacteria. There are other agencies, however, that contribute greatly to the rapidity of decay. Important among these are earthworms, larvæ of flies and beetles, and myriapods or thousand-legged worms. Animals of all these groups exist in myriads in the leaf litter. They eat the leaves, grind them, partially decompose them in the process of digestion, and restore them again to the soil, well prepared for the further decomposing action of the microscopic organisms of decay.

The importance of earthworms in hastening the decay of vegetal matter was pointed out long ago by Darwin in his classical studies on that subject. The importance of myriapods, however, as contributing to the formation of leafmold has not been adequately recognized. In the canyon of the Potomac River, above Washington, on the steeper forested talus slopes, especially those facing northward, the formation of alkaline leafmold is in active progress. The purer deposits are found in pockets among the rocks, where the leafmold is not in contact with the mineral soil and does not become mixed with it. The slope directly opposite Plummer's Island is a good example of such localities. Here during all the warm months the fallen leaves of the mixed hardwood forests are occupied by an army of myriapods, the largest and most abundant being a species known as *Spirobolus marginatus*. The adults are about 3 inches in length and a quarter of an inch in diameter. They remain underneath the leaves in the day time and emerge in great numbers at night. On one occasion a thousand were picked up, by Mr. H. S. Barber, on an area 10 by 100 feet, without disturbing the leaves. On another occasion an area 4 by 20 feet yielded 320 of these myriapods, the leaf litter in this case being carefully searched. Everywhere are evidences of the activity of these animals in the deposits of ground up leaves and rotten wood. Careful measurements of the work of the animals in captivity show that the excrement of the adults amounts to about half a cubic centimeter each per day. It is estimated on the basis of the moist weight of the material that these animals are contributing each year to the formation of leafmold at the rate of more than two tons per acre.

The decay of leaves is greatly accelerated also when the underlying soil is calcareous and alkaline, it being immaterial whether the lime is derived from a limestone formation or is a concentrate of the vegetation. On the rich bottomland islands of the upper Potomac the autumn leaf fall barely lasts through the following summer, so rapid is its decay. These bottomlands have an alkaline flora, and they are found to have an alkaline reaction, caused by the lime brought to them in the flood waters.

The acceleration of leaf decay by an alkaline substratum is due to the prompt neutralization of the acid leachings of the leaves and also to the fact that such a substratum harbors with great efficiency many of the most active organisms of decay, from bacteria to earthworms.

It must be understood that in a state of nature the decomposition of leaves is always so simple and uniform a process as been described, or that it always results in the formation of an alkaline leafmold. The chief factors that contribute to the acceleration of leaf decay have already been enumerated, but there are other conditions of nature that obstruct and retard this process. Under certain conditions the progress of decomposition may be permanently suspended long before the alkaline stage is reached. The soils thus formed, although high in humus like a true leafmold, have an acid reaction and a wholly different flora.

Examples of such suspensions of leaf decay are found in bogs, where the deposited vegetation is protected from the organisms of decay by submergence in non-alkaline water, and on uplands where the soil is derived from sand, sandstone, granite, or schist, in which there is not enough lime or other basic material to neutralize the acidity of the decaying leaves.

There is of course a supply of lime in the leaves themselves, and as a new layer of leaves is added to the soil

* Address of the retiring President, Washington Academy of Sciences, presented at the annual meeting of the Academy, January 16th, 1913, and published in the *Journal* of the Academy.

[1] For a description of the method followed in determining the acidity see Coville, 1910, p. 27. Experiments in blueberry culture. Bulletin 193, Bureau of Plant Industry, U. S. Dept. Agri.

each year it might be expected that there would result an unlimited concentration of lime in the surface soil and that all surface soils that supported a growth of vegetation would ultimately become alkaline. Such an indefinite accumulation of lime is prevented, however, by another factor which requires consideration. As soon as each successive layer of leaf litter is sufficiently decayed to permit the roots of plants to enter it and feed upon it, the lime it contains, together with other mineral constituents, begins to be absorbed. This loss of lime from the decaying leaves is sufficient, under many situations in nature, to prevent the decaying mass from reaching the alkaline stage. Decomposition is suspended while the leaf litter is still acid. True leafmold, with an alkaline reaction, is never formed under such conditions. The leaf deposit remains permanently acid and such areas bear an acid flora. In the vicinity of Washington one often sees hills of quartz gravel, wind-swept and rain-washed, where the soil contained little lime in the beginning, and none could be brought by flood waters or by the dust of the atmosphere. Characteristic plants of such hills are black jack oak, trailing arbutus, wild pansy, azalea, and huckleberry, all plants adapted to acute conditions of acidity. If one's front yard happens to coincide with what was once such a spot, let him not undertake the herculean task of growing roses and a bluegrass turf. Let his lawn be of redtop and his shrubs be azaleas, laurel, and rhododendrons.

Another factor that contributes to the suspension of leaf decomposition is the acid leachings from each new deposit of autumn leaves. Various acidity determinations show that after lying exposed to the weather over winter, leaves ordinarily have only one fifth to one tenth the acidity they possessed when they fell to the ground. It has been found experimentally that the leachings from fresh leaves will serve to acidulate an underlying soil of moderate alkalinity. Unless therefore the conditions of a locality are such as to effect the decomposition of one year's leaf fall before the next year's deposit takes place, a permanent acid leaf cover is established. In many of the oak forests on the sandy coastal plain eastward from Washington there is a permanent accumulation of such material. The roots of the trees and undershrub bind the half-rotted leaves into a dense mat. The principal trees are oaks. The principal shrubs that make up the dense underbrush belong to the Ericaceae and related families. There is no mellow leafmold nor any of the leafmold plants.

This kind of mat or turf is of such widespread occurrence, is so distinct in its appearance, and so characteristic in the type of vegetation it supports that it should have a name of its own, in order that it may come to be recognized as one of the important phenomena of nature.

Because of its resemblance to bog peat in appearance, structure, and chemical composition, and because it supports a type of vegetation similar to that of bog peat, it has been proposed to adopt for it the name upland peat. As defined in an earlier publication[2] upland peat is "a nonpaludose deposit of organic matter chiefly leaves, in a condition of suspended and imperfect decomposition and still showing its original leaf structure, the suspension of decomposition being due to the development and maintenance of an acid condition which is inimical to the growth of the micro-organisms of decay."

Upland peat would have become leafmold had not the orderly normal course of leaf decomposition been suspended and conditions of acidity established which rendered the progress of that decomposition impossible.

The rate at which leaves decay is greatly influenced by temperature. In the cooler northern latitudes and at high elevations in lower latitudes the rate of decay is slower and the formation of upland peat is more general than in warmer climates. Except on calcareous soils the higher Apalachian peaks, from 4,000 to 6,000 feet, bear an almost continuous layer of upland peat, from a few inches to a foot or more in depth. Their great rhododendron thickets are rooted in deep beds of upland peat. The spruce forests of the higher New England mountains lay down a similar formation.

In the treeless west the decay of leaves where it is not actually suspended by dryness is rapid and complete. At the higher elevations, however, where the land begins to be timbered the organic matter does not fully decay, and in the heavily timbered areas the deposit of upland peat often becomes characteristically deep and continuous. In fighting creeping fires in the yellow pine forests at the lower elevations the favorite and most effective tool is the rake, which parts the light leaf litter and puts a stop to the progress of the flames. But in the dense fir and spruce timber the forest ranger's chief tools are the spade and the mattock, with which he must cut through the thick layer of dry peat to the mineral soil beneath if he is to effectually combat a slowly creeping fire.

So strong is the tendency to the formation of peat under the low temperatures and heavy precipitation of the high mountains that even on limestone soils a superficial layer of upland peat is sometimes accumulated. Such a condition exists on innumerable areas at an elevation of about 10,000 feet in the Manti National Forest of Utah. On the basaltic plateau of extreme northeastern Oregon, where the soil is naturally alkaline in reaction the lodgepole pine and Douglas fir forests at elevations of 5,000 feet and over lay down a continuous bed of peat which supports a characteristic acid flora. A quantitative test of one of the acid flora soils of this region, at an elevation of 8,000 feet, showed the customary high acidity at the surface, and successively lower degrees of acidity underneath, until at the depth of 5 feet, at the surface of the basaltic rock, the reaction was neutral.

The group of plants that forms the best index to the acid character of a soil is the family Ericaceae, and the related families Vacciniaceae and Pyrolaceae. When these occur in vigorous growth on a calcareous soil or among calcareous rocks, as is sometimes reported, one may expect to find, as the speaker in his own experience has always found, that a layer of upland peat has been formed above the calcareous subtratum and that in this superficial layer the roots of the plants find their nourishment, really in an acid medium, notwithstanding the alkalinity beneath.

Continued observations on the association of certain types of wild plants with acid and non-acid soils, supported by cultural experiments, are in all respects confirmatory of the theory that soil acidity is one of the most influential factors in plant distribution and plant ecology.

The relation of leafmold to the existence of acid or non-acid soil conditions may now be viewed with appreciative recognition. If the conditions in any area are such that the decay of leaves follows the uninterrupted course that leads to the formation of leafmold a state of soil alkalinity is reached, with all the resultant effects on the growth and distribution of the native vegetation. If on the other hand the conditions are such that the course of decay is diverted into the channel that ends in the formation of peat, a condition of permanent acidity is indicated, with the accompaniment of all those peculiar plant phenomena which are characteristic of such a state.

It is perhaps desirable to call attention here to the fact that while partially decomposed vegetation appears to be the chief source of soil acidity there are mineral constituents of the soil, of wide distribution and great abundance, which are also acid in reaction. The acidity of which we hear so much in agricultural writings as characteristic of soils worn out by long years of careless farming is doubtless due in large part to a natural mineral acidity unsheated by the removal of the lime that once neutralized it for like the leaves of trees many of the crops of agriculture are heavy with lime and their uncompensated removal year after year has its cumulative result.

The speaker hopes that he does not overstep the proper bounds of this address if he calls attention to conditions in bog deposits which almost exactly parallel the two types of terrestrial organic formation, leafmold and upland peat. In bogs with alkaline waters, as for example those underlain by marl, a condition or permanent acidity is not maintained in the lower strata of the deposit. As far upward as the alkaline waters penetrate, the antiseptic acids are not present, decay continues, and the resulting formation is not peat, but a plastic fine-grained black material that may best, perhaps, be designated by that much misused term muck. Muck corresponds in bog deposits to leafmold in upland deposits, contrasting with bog peat as leafmold contrasts with upland peat.

We may follow this idea one step further. Coal is petrified peat. As the purest peats are not formed in alkaline waters, it can not be expected that the best coal will be found in situations indicative of alkaline conditions. If coal is found immediately overlying beds of marl or limestone it is to be expected that such coal will be of an impure type corresponding in origin to muck. The speaker takes the liberty of suggesting to his geological friends that in reconstructing in theory the climatic and other conditions under which the various kinds of coal were deposited they may safely hypothesize that the purer coals were laid down in waters that were acid.

Allusion has been made to the peculiar characteristics of plants that inhabit peat. Among these peculiarities perhaps none is more remarkable than the presence of mycorhizal fungi on the roots of many, perhaps most, peat-loving plants. It is known that peat is very poorly supplied with nitrogen in the form of nitrates, which most plants of alkaline soils appear to require. Organic nitrogen, however, is abundant in peat and there is very strong evidence that these mycorhizal fungi take up this organic nitrogen, and possibly atmospheric nitrogen also, and transfer it in some acceptable form to the plants in whose roots they live. Unfortunately the work of botanists on these fungi has been confined largely to the determination of the mere anatomical fact of their occurrence on the roots or in certain of the root cells, with descriptions of their size and configuration. Little attention has been paid to the isolation of the fungi, their culture and identification, or to the demonstration of their physiological action. The only hypothesis, however, that satisfactorily explains what we already know about the mycorhizal fungi is that they prevent the nitrogen starvation of peat-inhabiting plants. It is well known that certain peat-bog plants, as for example sundew, trap insects, digest them, and assimilate their nitrogen. It is to be hoped that within a few years we shall be equally well informed about the function of the mycorhizal fungi. But even now we may speak of their probable function with confidence.

The mycorhizal fungi are known to occur on most of the trees that inhabit acid situations, for example chestnut, beech, oaks, and conifers. The ordinary hillside pasture in New England is a mycorhizal cosmos. The clubmosses have them, the sweet fern, the blueberries, the ferns, the orchids. In our sandy pine and oak woods about Washington almost all the vegetation possesses mycorhizal fungi One comes to think of the giant oaks as dependent on these minute organisms.

Were Solomon to write a new edition of the Proverbs to-day I am sure that he would tell us "There be four things which are little upon the earth, but they are exceeding strong," and that among the four he would include "The little brothers of the forest, they seek not the light but the leafy earth; they prepare for the oak the strength that is his."

Our American agriculture, derived in the main from the agriculture of the Mediterranean region, and that in turn from the older agriculture of Persia, is chiefly made up of plants that thrive best in alkaline or neutral soils. Although many of our soils in the eastern United States are naturally acid we try with only indifferent success to grow in them these alkaline plants of southern Europe and the East. Although some of our agricultural plants are tolerant of acidity, our agriculturists have not yet recognized the possibility of building up for acid soils a special agriculture in which all the crops are acid-tolerant. We may yet, perhaps, utilize for agricultural purposes even the sandy acid lands of the coastal plain instead of turning them over as we now do to the lank huckleberry picker, whose lonesome garden is all that he is able to reclaim by present methods from the imaginary wilderness that surrounds him. Yet these lands contain all sorts of delicious native fruits, and a natural vegetation rich and luxuriant after its own manner.

Had our agriculture originated not in the alkaline soils of the Orient but among the aboriginal peoples of the bogs of Scotland or of the sandy pine barrens of our Atlantic Coastal Plain we should have entirely different ideas of soil fertility from those we now possess. If our cultivated fruits were large and otherwise improved forms of the blue berry, the service berry, the thorn-apple, and the beach plum, if our only grains were rye and buckwheat, and our only hay redtop and vetch, and if our root crops consisted of potatoes, carrots, and onions, our high-priced agricultural lands would be the light sandy acid soils and the drained bogs, while our deep limestone soils would be condemned to use for the pasturage of cattle and of sheep.

Thus far man has devoted himself largely to the utilization of the plants of the leafmold, which have gathered up for him the wealth of the earth. Let him now, I say, turn his attention also to the plants of the peat and try whether they will not yield to him in increased measure the luxuriance of foliage and of fruit that they have always yielded without assistance to nature herself.

[2] Coville, 1910, p. 34. Experiments in blueberry culture Bulletin 193, Bureau of Plant Industry, U. S. Dept. Agri.

Unusual Roller Gaging Device

Probably very few persons are aware of the extreme accuracy that is absolutely essential in the manufacture of ball and roller bearings, though even passing thought will reveal that if one ball or one roller in a bearing is ever so slightly over size it will be considerably overloaded and one that is under size the minutest fraction of an inch may carry no load at all. In every bearing factory instruments and devices of the utmost precision are used to insure the greatest possible accuracy. Obviously, however, where millions of balls and rollers are turned out it is practically impossible to have the limit of error in every one of them exactly the same despite its desirability; there is bound to be a slight difference that may be almost so small as to defy detection by commercial methods. It was to obviate trouble resulting from such inaccuracy that the machine shown on our title page was perfected; it is used by one of the largest roller bearing manufacturers in the country. With this device, the rollers are fed onto a rotating steel disk and passed in turn in front of delicate plungers arranged around the periphery of the disk; these plungers are in fact super-sensitive gages capable of detecting differences of one quarter of a ten thousandth of an inch. When a roller touches a plunger, electrical contact is made and the mechanism then drops the roller into a canister. The next roller may not touch a gage until it has made almost the complete circuit, but it must touch one of them and thus find its way into one of the receptacles. In making up the assembled bearings, all the rollers in any bearing must come from the same canister, thus insuring that all of them are as nearly the same size as human ingenuity can make them.

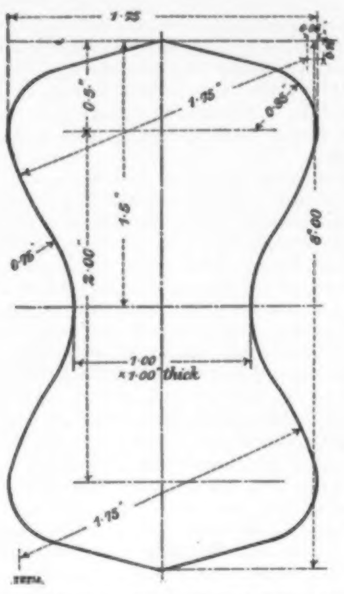


Fig. 1.—English Standard Test Briquette.

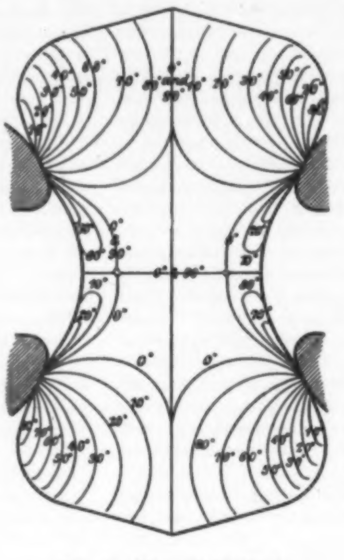


Fig. 2.—Map of Isoclines.

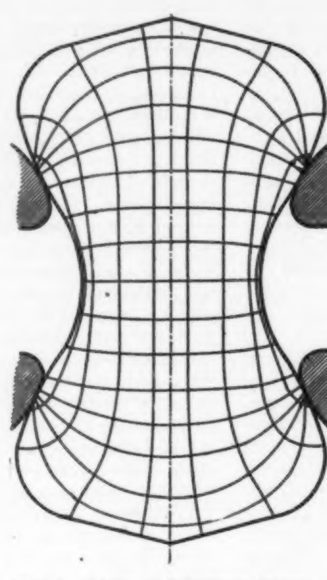


Fig. 3.—Lines of Principal Stress.

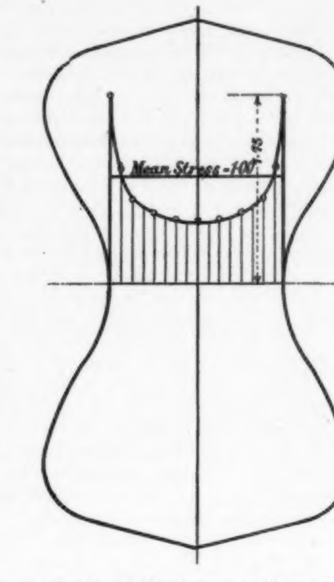


Fig. 4.—Ratio of Maximum to Mean Stress.

The Distribution of Stress in a Cement Briquette*

An Optical Method of Great Elegance for the Investigation of the Strains in a Body Under Stress

By Prof. E. G. Coker, M.A., D.Sc.

The importance of standard methods of testing the strength and other properties of cement is recognized wherever such material is used in quantity, and for the chief countries of the world elaborate specifications have been drawn up, which in some cases are Government standards, and in others are adopted by the representative engineering bodies chiefly concerned in the use of the material. In general, therefore, some precisely defined method has the prestige of authority, and is accepted as the standard way of testing the material. In comparing the specifications used in different countries, it is hardly a matter for surprise that differences exist, owing to want of agreement in standards of length, mass, and other causes, some of which are perhaps unavoidable, while others might easily be uniform for all countries if an agreement could be arrived at. Owing to the differences in the standards thus set up, it is extremely difficult, if not impossible, to make an effective comparison of cement tests according to different specifications, and this sometimes acts in restraint of trade, and is therefore a matter of commercial importance. These differences are especially marked in the case of tension tests, and are mainly owing to the variety of shapes of the briquettes and gripping devices used in testing. The forms of the standard briquettes used in America, in England, and on the continent of Europe show that expert opinion is far from being unanimous as to the best form to use, and very few data appear to exist which will enable an effective comparison to be made of the influence which shape has on the strength of the briquette.

* Paper read before the International Association for testing materials.

It is well known that a sample of cement will give values of the tensile strength, which depend to a considerable extent on the form of briquette, and this is apparently due to want of uniformity in the stress distribution across the minimum section. Some attempts have been made to experimentally determine this variation notably by Föppl,[1] who has measured the strains in an india-rubber model, while Durand Claye[2] has shown how to approximately calculate the variation of stress across the minimum section.

An optical method of determining the stress distribution in a model briquette, appears to offer some advantages in the treatment of this problem from an experimental point of view, and a few experiments have been made, since the author received an invitation to contribute a paper to the Congress, which are sufficient to explain the method of treatment now being pursued. It is well known that many transparent bodies, like glass and celluloid, become temporarily double refractive under stress, and a beam of polarized light in passing through the material is resolved into two component rays, which travel at different velocities in the material, and therefore have a phase difference on emergence depending on the intensity of the stress. This phase difference may be determined in various ways, and a measure of the stress at different points in the body can be obtained.

The properties of cement, as regards its elastic behavior, no doubt differ considerably from glass or other transparent materials, and therefore the results obtained by an optical method may not possess the same value as direct measurements on the cement itself; but an experimental determination of the stress distribution in a briquette of cement, or of cement and sand, presents very great, if not insuperable difficulties, while an optical method is easy to apply and also affords a simple means of comparing different forms. It is probable that the stress distribution in a cement briquette is somewhat different from that of a model made in glass or other transparent material, yet a comparative study of different models is of value, since it gives a general idea of the stress distribution, and enables a comparison to be made of the variation in the stress at the minimum sections of different forms.

It may be urged that no transparent material has the same ratio of resistance to tension and compression which cement possesses, but much of this objection disappears if the experimental work is limited to a range of stress in which permanent deformation does not take place.

As an illustration of the method of optical study, we may take any one of the well-known forms, such as the English standard shown in outline by Fig. 1, and shape a model in transparent material for use in testing on a scale convenient for the optical appliances available. If this model is placed in shackles of the prescribed form, and subjected to load in a tension-testing machine, it will become doubly refractive, and when viewed in polarized light will show the well-known color effects due to this acquired property. Such a stressed specimen is shown in the accompanying Fig. 5, which is a reproduction of a photograph of a briquette cut from a sheet of celluloid and stressed in the usual manner. The stress is here made apparent to the eye in the form of a picture of systems of color bands,[3] which mark the stress intensity, and their distribution on the specimen shows, in general, the way in which the stress varies. At the points of application of the load for instance, the numerous bands of color show very clearly how intense the stresses are in the neighborhood of these points, and the rapid changes which occur as these points are approached. The same effect, although in a much less degree, is seen at the waist of the section, especially at the extremities of the minimum section, where color bands indicate a considerable rise in the stress at these points.

It can be shown that these color effects are proportional to the difference of the principal stresses at a point, and therefore the optical effect is directly proportional to the shear in the material.

The color effects do not enable the eye to distinguish

[1] A. Föppl, Vorlesungen über Technische Mechanik, Band III., Seite 9.

[2] Annales des Ponts et Chaussées, Tome 9, Serie 7, 1895.

[3] The original monograph contains a very fine reproduction in colors of the photograph here described. We regret that the conditions of our presswork do not permit us to render the colors in the natural state here.

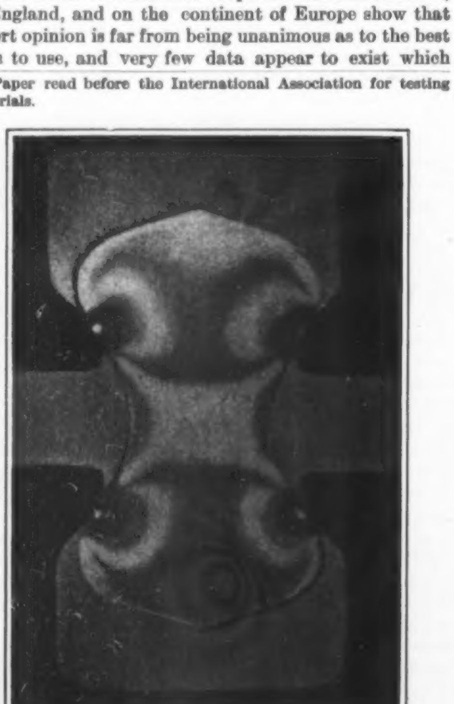


Fig. 5.—A Stressed Sheet of Celluloid.

Fig. 6.—Lines of Principal Stress (Dark Bands).

compression stress from tension stress, but this may be accomplished as shown by Hönigsberg and Dimmer[4] by interposing in the field of view a three quarter wave plate of selenite or the like, which has the effect of causing those parts in compression to appear of a reddish tint, while the parts in tension appear of a bluish tint. For purposes of measurement of stress intensity it is generally most convenient to arrange a second simple tension or compression member in a direction along one of the lines of principal stress, and subject this second specimen to load until a dark field is obtained. The load so applied measures the difference of the principal stresses at the point under observation in the material. In many cases the axes of principal stress at a point in a body can be obtained by calculation, and the direction of the calibration member determined. Where no theoretical data exist, we may still determine the directions of principal stress, if we avail ourselves of the optical properties possessed by polarizing and analyzing prisms of selecting those rays of light for transmission which correspond to their own principal planes. If we arrange the polarizer and analyzer of our optical combination in the usual manner, with their principal planes at right angles, the combined arrangement will effectively stop all plane rays vibrating in either of these directions, and since at any point of a briquette the refracted rays are polarized in the directions of principal stress, we can obtain the directions of these latter by observing the positions of the dark bands as the specimen is rotated in the field of view. The optical appearance presented by a briquette in one such position is shown by Fig. 6 in which all the positions of principal stress at the corresponding inclinations of the Nicol's prism are marked by the black bands shown in the photograph. A map of the center lines of the whole series of such black bands, is shown on the accompanying Fig. 2 with the angular position of the specimen marked with reference to the axes of the polarizing prisms. If we now draw curves intersecting the isoclinic lines at the given angles we obtain the lines of principal stress, and Fig. 3 shows a series of lines drawn in this way, and covering the specimen. The position of the calibrating specimen is therefore determined for any point, and the difference of the principal stresses can be obtained directly. In general, the principal stresses can only be obtained separately from the relations between shear stress and principal stress, and this usually involves much labor; but in the case of the minimum section of a briquette it is of especial interest to note that the maximum stress difference occurs at the boundary where the radial stress vanishes, so that the maximum tension can be directly obtained, and compared with the mean average stress for the section. For the briquette under consideration, the values obtained experimentally are shown in Fig. 4 giving a ratio of maximum to mean stress of 1.75 approximately.

In a similar manner the American standard shows a value of 1.70 for this ratio and the Continental form gives 1.95. These rough measurements indicate the want of agreement in the stress distribution over the minimum section, and they all show what an important factor the form of the briquette is. Experiments on a larger scale would probably give more accurate values, but the present figures indicate, to a first approximation, the probable want of agreement in the stress distributions across the minimum sections of standard briquettes now in use. They show why the comparison of tests of briquettes made according to different specifications, is likely to lead to error, and they indicate that it is extremely desirable for all briquettes to have the same ratio of maximum stress to mean stress. Whether it is desirable, or possible, to make this ratio unity, could no doubt be ascertained by trial, but it is sufficient here to show that optical measurements of stress in models, like the present examples, afford an extremely useful means of obtaining information as to stress distributions, which can often only be obtained by other means with extreme difficulty, or perhaps not at all.

[4] Brussels Congress Int. Ass. Test. Mat., 1906.

Cinematography Carried to Extremes in the Marey Institute

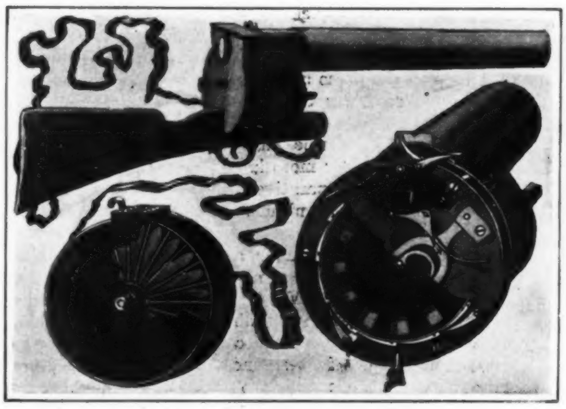
THE Marey Association of Paris, founded in 1898, has for its object the study of means for comparing the various recording apparatus used in physiological laboratories, and the attainment of uniformity in the methods of physiological study. Marey made a special study of movement, as readers of the SCIENTIFIC AMERICAN will remember from a former article. M. Weiss, assistant director of the Marey Institute, founded by this association, recalls with legitimate pride, that, except the perforation of the strip, due to Edison, which insures the perfect reversibility of the machine, the successive improvements of the cinematograph were all obtained in Marey's laboratory. This, says *Le Temps*, is a little-known page in the history of science, and one worth retracing.

M. Janssen's "astronomical revolver," devised by him in 1873, for the purpose of recording the tranist of Venus over the solar disc at intervals of 70 seconds, seems to have been the first realization of chrono-photography, the embryo of our cinematograph. Marey modified Janssen's contrivance and achieved his "photographic gun," in which a plate inclosed in the barrel turns by jerks, photographing the flight of a bird 12 times in a second, each exposure lasting one five-hundredth part of a second. In this way, however, only silhouettes were obtained, the object being defined against a bright background, and innumerable experiments were necessary to get a black background that should throw the images clearly and not make any impression upon the plates.

To avoid confusion of the images of men or animals taken at short intervals, Marey conceived the plan of not photographing the whole object, but only points or lines on the body which by their positions in the images show the movement under investigation. A man dressed all in black, and therefore invisible in a dark field, wears silver trimmings covering the axis of his limbs: thus arrayed, and passing before the apparatus, he will produce images reduced to mere geometrical diagrams.

When photographic films were invented, Marey was the first to think of using them for obtaining a large number of images per second, which had been impossible with glass plates, owing to their inertia and their breaking whenever the movements of rotation went beyond a certain limit of frequency. In 1893 he succeeded in obtaining a regularly punctuated rotation of the films, and faithfully reproducing movements, both rapid and slow.

Marey's researches constitute a valuable basis for a comparative mechanics of animal locomotion and the explanation of certain mysterious facts—such as the famous paradox of the cat always falling on its feet. He recognized that if the images are photographed at the rate of 60 per second, they can be made to pass before the eye at the rate of only 10 per second; this is enough to produce the appearance of absolute continuity of movement, only, being six times as slow as in the reality, the phenomenon can be grasped in all its detail. Different gaits in walking can also be studied at leisure, and the fine arts have profited by Marey's photographs: thanks to them, it has been possible to establish the common mistake of painters in representing a running man as leaning forward, when, as a matter of fact, the torso is perfectly erect.



Marey's Photographic Gun.

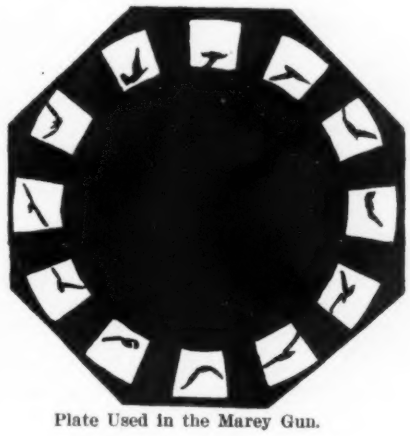


Plate Used in the Marey Gun.

Marey succeeded in obtaining more than a hundred images per second, and was thus able to register the most complex movements of many animals. But when the duration of the phenomenon is less than one-hundredth of a second—as in the wing-movements of most insects—much more rapid machines must be used. Mr. Bull has lately perfected an apparatus which will take as many as 2,000 photographs per second. In this case, of course, there can be no such thing as stopping the film for each exposure: it is mounted on a drum and rotated with a lineur velocity of nearly 40 meters (133 feet) per second. The image of the object is formed on this film. The whole view is in darkness, its lighting being effected by a very brilliant electric spark passing between two magnesium points. The spark being instantaneous, the photograph is clearly defined. A very simple arrangement produces a certain number of illuminations for each turn of the drum. Thus, by revolving the film in an ordinary cinematograph, the phenomenon can be reproduced on the screen at a much lower rate of speed. Mr. Bull has films showing the breaking of a soap bubble by a revolver bullet and others showing the flight of insects. One great difficulty is to start the apparatus at the exact moment when the insect crosses the photographic field. As this cannot be done by the operator's hand, Mr. Bull has contrived a marvelous arrangement by which the insect itself becomes operator.

This apparatus, unfortunately, owing to the practical difficulty of lighting a large field, is applicable only to movements of small extent. Besides, as the film is of no great length, the number of photographs obtainable is very limited. M. Noguès has made efforts to devise an apparatus much more rapid than the ordinary cinematograph and yet capable of a large number of photographs. He has succeeded in obtaining 180 images, and even more, per second. Thus the slightest movements of a pigeon's wings, the most fugitive attitudes of a swift runner, are fixed and afterward reproduced at one tenth or one fifteenth their actual velocity, presenting a study which is not only very amusing, but also very instructive.

But the ambition of the scientists know no bounds: having thus recorded the external movements of animals, they are now thinking of seizing the movements of internal organs, following the contractions of the heart step by step, witnessing the still mysterious actions of the stomach and the intestines. Ordinary light, of course, is out of the question here; the X-rays must be used, after the organs have been rendered distinguishable by darkening them with salts of bismuth. This is the radio-chronophotography upon which many scientists are already now working, and which will in the near future be as easy of accomplishment as ordinary cinematography.

How to Tell Artificial Silks

ARTIFICIAL silk is fast coming to be a very important textile material and is being used in ever increasing quantities by the trade. It is employed as an adjunct not only to the silk industry itself but is also being used in connection with wool and cotton in the preparation of a great variety of fabrics. It is even being used largely in knot goods and hosiery in combination with cotton and mercerized cotton.

The dyer therefore is meeting more and more with this product, and as there are three different kinds of artificial silks in general use, and as these different varieties possess certain differences in structure and quality, it really becomes a question of considerable importance to the dyer to know one variety from another. This is more especially important because one silk may stand a treatment which would be fatal to another.

The three artificial silks now to be met with on the market are described in a recent issue of the *Wool and Cotton Reporter* as follows:

1. Collodion silk, known as Chardonnet, or nitrosilk. It is prepared from nitrated cotton.

2. Cuprate silk, known as Glanzstoff, Pauly, Elberfeld silk. It is prepared from a solution of cellulose in cuprammonium solution.

3. Viscose silk. This is prepared from a solution of cellulose in a mixture of caustic soda and carbon bisulphide.

In their outward appearance the three forms of artificial silk are so nearly alike that it would not be possible to distinguish between them. Even a microscopic examination by an experienced observer does not lead to any positive conclusion as to the kind of silk.

A fairly simple test, however, according to *Paper*, and one which may be easily carried out by the average dyer, is the following: A sample of the silk to be tested is placed in a small porcelain dish and concentrated sulphuric acid is poured over the fibers. If the sample consists of collodion silk no coloration appears until about an hour has elapsed, when the acid solution will acquire a pale yellow color.

In the case of cuprate silk the acid becomes yellow immediately, and the color becomes deeper on standing. In viscose silk the acid immediately develops a reddish brown, deepening to a rusty brown.—*Chemical Engineer*.

The Double and Binary Stars*

Over Ten Thousand Twin Stars Are Known

By F. W. Henkel, B.A., F.R.A.S.

". . . . Other Suns, perhaps,
With their attendant moons, thou wilt descry
Communicating male and female light,
Which two great sexes animate the World,
Stored in each orb, perhaps with some that live."
—*Milton* ("Paradise Lost," VIII, 148-152).

Though the Copernican hypothesis of the Earth's motion round the Sun was immensely strengthened by the discoveries of Galileo, and the Newtonian theory of gravitation supplied the *modus operandi* for this motion, yet the objection of the opponents of Copernicus that the stars do not *appear* to move as they should do in consequence of that motion, long remained a serious difficulty. "Were the Earth in motion in a mighty orbit round the Sun," said they, "spectators on our planet would, without difficulty observe displacements in the relative positions of the stars during the course of the year, the nearer stars moving more and the more distant ones less, just as objects in the surrounding landscape appear to move when seen by a spectator in a moving carriage." But no such motions could be detected, and all that could be answered was that the distances of the stars are so vast that the size of the Earth's orbit is but an insignificant quantity in comparison. It was no doubt partly on account of his difficulty in accepting this explanation that Tycho Brahe was led to reject the Copernican views, since his observations had not enabled him to detect any "parallactic" change of place due to the Earth's supposed motion, and his measurements of the apparent diameters of the stars had led him to conclude that the brightest of these objects would be of enormous dimensions (greater than the whole Earth's orbit) were the Copernican hypothesis true. After the invention of the telescope it was seen that the apparent diameters of the stars were very much less than had been assumed to be the case by Tycho and others and up to the present time the true diameter of a star has never been measured, being less than the *minimum visible*, the disk seen by the naked eye being an optical illusion, an effect of irradiation.

Galileo, in one of his "Dialogues on the Systems of the World," proposed that pairs of stars seen close together in the sky should be observed and their relative position noted and distance measured throughout the year. If one of these objects be nearer to us than the other, it will be displaced and the angles and distances will change regularly in that interval of time. The same idea was suggested by others, but the first to carry out the suggestion systematically was Sir William Herschel. The latter, finding many cases where two or sometimes more stars lie close together in the sky, and supposing the brighter component was nearer to our system than the fainter one, made numerous measurements, expecting to find regular annual variations due to this supposed difference of distance, in other words, parallactic displacement.[1] But instead of finding this Herschel detected a regular progressive change of quite a different nature, showing sometimes that one of these bodies was describing an orbit round the other, or that both were traveling together throughout space. In his own words he "went out like Saul to seek his father's asses, and found a kingdom," the existence of systems (of Stars) of a different and higher order from that prevailing in our own system, binary and multiple stars. A distinction was thus made between stars optically connected which merely lie nearly in the same direction, as seen from our planet, but may be as far removed from one another as they severally are from our system, and stars physically connected, systems consisting of two or more members moving round a common center, or in nearly parallel paths in a common direction. All over the sky there are to be found cases of two or more stars lying much closer together than the average distances of the stars from one another, and perhaps as many as twelve thousand such couples are known, the *double stars*. Some of these doubles have components of nearly equal brightness (e. g., the two components of α Centauri, the nearest of all external celestial objects to our system, so far as is yet known, and the two components of 61 Cygni, the next nearest system, both of these are also *binaries*); in other cases the members are of very unequal magnitudes, like Sirius and its companion, the former being the brightest of all the stars visible to us, while the latter is only visible by the help of the most powerful telescope, and was not detected till 1862. In that year the late Alvan Clark first saw it with the recently finished Chicago refractor, the then largest instrument of its kind in the world. Several hundred binary systems are now known with more or less certainty, moving in elliptic orbits round common centers, the orbits in some cases being almost circular, in others very oval and "eccentric." There are also systems of three or more stars, the trinary and multiple stars. The star ζ Cancri consists of two larger and fairly close members revolving in nearly circular orbits round their common "center of gravity," with a third fainter and more remote body, while ε Lyrae consists of two pairs of stars, and the multiple star θ Orionis, not far from the center of the great Nebula, consists of four principal stars and two minute companions very close to two of the brighter, "to perceive *both* which is one of the severest tests which can be applied to a telescope" (Sir John Herschel), but three of the four brighter were detected by Huyghens, in 1656. Though, as we have just seen, the number of double stars known to modern astronomers, and visible through the telescope, is thus considerable, yet the angular distance of the components is too small to admit of their detection by the unaided eye in pre-telescopic days, so that though a few clusters were known to the ancients, the first double star which attracted attention seems to have been ζ Ursae Majoris, Mizar in the Great Bear, which was noted as double by Riccioli about the middle of the seventeenth century (Lewis). This was also the first star to be photographed as double, by G. P. Bond, in 1857, and also the first "spectroscopic binary," a class of objects of which we shall hear more later on. It is curious, too, that there is comparatively close to Mizar, which is of the second magnitude, a faint star, Alcor, just visible to the unaided eye, and it is said that the Arabs considered its detection as a test for keen eyesight. This star is said to be sometimes known as "Jack by the Middle Horse," Mizar being thus the "Middle Horse" pulling "Charles' Wain." Dr. Hooke, in 1665, discovered that γ Arietis consisted of two fourth-magnitude stars, eight seconds of arc apart. During the eighteenth century the well-known doubles, α Centauri, γ Virginis, Castor, 61 Cygni, β Cygni, ε Lyrae, α Herculis, and ζ Cancri were added to the list. This last star was discovered by Christian Mayer, a Jesuit priest living at Mannheim, and shortly before his death, in 1781, he published a catalogue of all double stars known up to that date, including his own additions, making a total of eighty-nine pairs. For the first time he hazarded the suggestion that some at least of these pairs must be physically connected, a suggestion fully confirmed a few years later. As already mentioned, when first discovering and observing hitherto unknown double stars, Herschel hoped to employ them to determine parallaxes, but continued the work with other ends in view. His first catalogue contained two hundred and sixty-nine pairs, and its examination by the well-known philosophical writer, the Rev. John Michell, the "ingenious Mr. Michell," as he is called by Mr. Lewis, led him to make the following remarks. He says: "The very great numbers of stars that have been observed to be double by Mr. Herschel, if we apply the doctrine of chances, cannot leave a doubt with anyone that by far the greatest part, if not all, of them are systems of stars so near to each other as probably to be liable to be affected sensibly by their mutual gravitation, and it is, therefore, not unlikely that the periods of some of these about their principals (the smaller ones being upon this hypothesis considered as satellites to the others) may some time or other be discovered." We may assent to the conclusions, or rather to the probable meaning of their author, without committing ourselves to approval of his language. It was not, however, till 1803 that Herschel made the definite statement that some of these combinations were indeed binary, in a paper which he contributed to the *Philosophical Transactions* of the Royal Society. This he justified by his examination of the measures of *Castor*, γ *Leonis*, γ *Virginis*, δ *Serpentis*, and ε *Bootis*. Of seven hundred and two double stars contained in Herschel's two catalogues, the members were divided into six classes according to their angular distance apart.

Class I	contained	97	pairs separated	less than 4 inches.
Class II	"	102	" "	from 4 to 8 inches.
Class III	"	114	" "	" 8 to 16 inches.
Class IV	"	132	" "	" 16 to 32 inches.
Class V	"	137	" "	" 32 to 60 inches (1 foot).
Class VI	"	121	" "	over 60 inches.

Since Herschel's day the whole subject of double-star astronomy has been vastly extended, and our knowledge greatly increased by the labors of a host of professional and amateur workers. Among the foremost of these must be placed the name of F. G. W. Struve, of Dorpat, whose classic work, familiarly known as the "Mensurae Micrometricae," still remains the standard authority "for method and arrangement." This catalogue, published in 1837, contains measures of two thousand six hundred and forty pairs of stars, three fourths of the ten thousand four hundred and forty-eight measures being made by Struve himself without assistance, but during the latter part of his work he had the assistance of his son and other observatory assistants, "who entered the reading and turned the dome, but made no measures." These measures have been collected, compared and discussed with much other information relating to double stars in a volume by Mr. Thomas Lewis, F.R.A.S., of the Royal Observatory, Greenwich, published in 1906 (*Memoirs of the Royal Astronomical Society*, vol. LVI). Struve's work comprised a general survey of the sky between the North Pole and 15.5 degrees declination, about 0.63 of the whole sky. His plan of work was (1) to discover and catalogue double stars; (2) to make micrometer measures of them; (3) to estimate the magnitude and note the colors; (4) to fix the places by meridian observations. Between February 11th, 1825, and February 11th, 1827, he examined one hundred and twenty thousand stars from the first to the third magnitude, and found three thousand one hundred and twelve double stars, whose distance apart did not exceed 32 inches.

Many of the double stars exhibit the remarkable phenomenon of contrasted colors, but it has been remarked (Proctor, "Old and New Astronomy," page 783) that this is never the case when the two adjacent stars are of nearly equal magnitudes, and it appears to be the universal rule that when there is a contrast of color the tint of the fainter star lies more toward the violet (more refrangible) end of the spectrum than that of the other. Thus, the brighter star being reddish or yellowish will have a green or blue companion. Sir John Herschel, who worthily continued his father's work, and also contributed what he modestly calls his "mite" toward double-star astronomy, has suggested that this complementary coloration is "probably in virtue of that general law of optics that when the retina is under the influence of excitement by any bright light, feebler lights, which when seen alone would produce no sensation but of whiteness, shall for the time appear colored with the tint complementary to that of the brighter." There are, however, difficulties in the way of accepting this explanation in all cases, and others are inclined to regard this contrast of colors as being, in some cases at least, due to a real difference in the physical nature of the stars. However this may be, the beauty of the sights visible to the telescopist is greatly enhanced by the wonderful display of colors given by different celestial objects. It is often found that if in a double-star system the colored star be much less bright than the other, it will not affect the latter's color. Thus, for example, η Cassiopeiae is composed of a large white star and a fainter one of a "rich ruddy purple." A pleasing picture of the curious alternations of illumination that would be produced for the inhabitants of a planet circulating round a pair of colored double stars may be drawn, and is given by Sir John Herschel ("Outlines of Astronomy," page 851). Suppose a planet revolving round a red and green sun. When the red sun rises there will be daylight, and "all will be red." Bye and bye the green sun will rise and mount higher above the horizon. The light will gradually change from a reddish tint to pure white. Later on, the red sun will set, and the remaining illumination, will consequently be green. Last of all, the green sun will set, and darkness will set in. Thus, we have the alternations red-day, white-day, green-day, and night, the colors of all objects undergoing corresponding variations.

It is a remarkable fact that though isolated red stars are found in most parts of the sky, no decided green or blue star has ever been noticed unassociated with a brighter companion (Herschel).

We have already stated that the orbits of binary stars round their center of mass are ellipses, usually much more oval than the planetary orbits in our solar

* Reproduced from *Knowledge*.

[1] Parallax is the name given to an apparent displacement of an object due to a real displacement of the position of the observer. Technically, the parallax of a star is the angular value of the semi-diameter of the Earth's orbit (which is greater as the star is nearer), as seen from the star.

system, the average eccentricity of the visual binaries being about 0.5 (see "Researches," vol. II, chapter 20), but it is a remarkable and interesting fact that the closer "spectroscopic" binaries move in much more nearly circular orbits. The application of the spectroscope to stellar astronomy has not only given us information otherwise unobtainable as to the chemical nature of the heavenly bodies, but it has also enabled us to detect hitherto unsuspected motions, and has rendered known the existence of bodies perhaps for ever invisible to our telescopes. By means of this instrument it has been ascertained that the number of binary stars is far greater than anyone had previously imagined, but that in most cases the components are too near together to be separated by the most powerful telescope. According to estimates based on the work done at the Lick Observatory, Campbell found that about one star in five of those examined proved to be a spectroscopic binary, and in certain groups this ratio was found by Frost to be as high as one third (See). The telescope discloses only the widely-separated and luminous companions among the systems nearest to us in space, but the spectroscope enables us to detect all attendant masses which are large enough perceptibly to disturb their luminous "fellows," whatever be their distances, thus enormously increasing our knowledge of stellar systems. When a star is approaching us the dark and bright lines in its spectrum are shifted slightly toward the violet; when it is receding they are shifted in the opposite direction, and by the comparison of well-known lines thus changed in position with their ordinary position as seen in terrestrial spectra it is possible to determine the speed of their motion. Thus, the well-known variable star, Algol, exhibits changes in its spectrum indicating that the velocity in the line of sight undergoes variations, being alternately toward and away from the Earth, and thus is confirmed the view that its variability is due to partial eclipse by a revolving dark satellite, the "stupendous dark globe." It has been shown, too, that α Virginis, like Algol, has a massive dark companion which, however, does not eclipse, as it does not come between the star and our position. Other double stars have been discovered in which both components are bright, so that at one part of their orbit the lines common to the spectra of the two stars appear double and separated, gradually closing up till they appear single and then opening out once more. Since visual binaries with known orbits are found to give variations of a similar character in their spectra and have thus come to be included in the class of spectroscopic binaries as well as "visual" ones, but so far no spectroscopic binaries first discovered as such have been resolved telescopically, we see that the difference merely consists in the smaller size of their orbits and consequent shorter periodic times of revolution of the latter. Periods of a few days, or even hours, are known for these, while the shortest periods for a visual binary yet known is that of δ Equulei (5.7 years) and orbits with periodic times of hundreds of years have been calculated for some of the more widely-separated binaries (γ Virginis, 182 years; σ Coronae, 340 years, Lewis). When the angular dimensions of the orbit and the parallax of the system are known, the real dimensions (in miles, kilometers, and so on) are easily calculable, and from a knowledge of the periodic time of revolution the total mass of a binary system may be obtained from the extension of Kepler's third law, assuming the motion due to an action of a gravitative character. Let M_1 and M_2 be the masses of the two components, respectively, M and m the mass of the Sun and Earth.

Then $$M_1 + M_2 = \frac{a^3}{R^3}\,\frac{T^2}{p^2}\,(M + m)$$

where T = Earth's period of revolution = 1 year and R = the semi-axis major of its orbit, the astronomical unit; a and p being the semi-axis and periodic time, respectively, of the stellar system. Thus, our formula becomes

$$M_1 + M_2 = \frac{a^3}{p^2}$$

giving the mass of the system in terms of the Sun's mass as unity.[2] Thus we find the masses of many of the binary systems are comparable with that of the Sun, some being rather smaller, others considerably greater.

Of fifty-three orbits of spectroscopic binaries dealt with by Dr. See, he finds that the mean eccentricity of these orbits is considerably less than that of the visual binaries, being only 0.23 instead of 0.5, as for the latter, a point which has important bearings on Cosmogonic theory. The average period for these fifty-three systems is about thirty-seven days, but if we exclude a few long period stars, the average period of all the rest is about ten days. From the formula

$$M_1 + M_2 = \frac{a^3}{p^2}$$

assuming the average mass of the spectroscopic binaries to be about the same as that of the visual ones, and taking $M_1 + M_2 = 1$, we find the average value of the mean distance to be 0.2173 astronomical units, when p = 37 days or 0.09 when p = 10 days. Thus the average dimensions of these orbits are less than that of the planet Mercury, and it seems probable that for such orbits the efficacy of tidal friction as a possible agency in changing their forms may not be overlooked. The late Sir George Darwin, whose recent death we have to deplore, and whose researches on the problems of fluid motion and tidal friction generally are well known, was of opinion that many double stars have been generated by the division of primitive and more diffuse single stars, in a manner somewhat analogous to that in which he supposed that our own Moon came into being. Many difficulties, not altogether ignored by Darwin himself, prevent our acceptance of his views as regards the origin of our satellite, but there appears more reason to consider that the fission theory of the origin of double stars is a true one. Such fission would give rise to nearly circular orbits, and though this is not the case with the known systems, it is more true for the nearer spectroscopic binaries than for the more widely separated visual ones. But it has been shown that when two bodies of not very unequal masses revolve round one another in close proximity the conditions are such as to make tidal friction as efficient as possible in transforming the orbits. Hence, we have in tidal friction a cause which may have not only sufficed to separate the two component stars of a double star system from one another, but also to render the orbit eccentric (Darwin). Thus, it may be that under this influence in the course of time the orbits of the spectroscopic binaries will increase and become more eccentric, more nearly like those of the "visual" binaries. On the other hand, it is not impossible that some of these orbits may be shortening and becoming more nearly circular under the action of the resisting medium, whose long-continued action affords the best explanation yet advanced of the comparative circularity of the orbits of the planets in our own solar system. The efficacy of tidal friction (whose tendency is to produce increase of eccentricity and distance) is greater as the mass-ratios of the bodies acting and acted upon are more nearly equal, as in the components of a double star system, and least when one mass greatly preponderates, as in our own solar system, where the mass of the Sun exceeds that of all the planets put together more than six hundred times. "The preponderance of high eccentricities among the equal pairs seems to be an indication of the higher efficacy of tidal friction, or of the lesser importance of the action of a resisting medium in such systems," and so, while deducing one confirmation of the action of tidal friction and the resisting medium from the small size and roundness of the orbits of the spectroscopic binaries, we may find an additional verification of this theory in the larger eccentricities occurring among binary stars with nearly equal components. We may, too, if we please, derive important conclusions as to the relative ages of the various systems. Thus, from the theoretical researches of Sir G. Darwin on tidal friction, supplemented by the long imperfectly recognized agency of the resisting medium, Prof. See has for the first time succeeded in giving a reasonable account of many remarkable features in the phenomena of the starry heavens, and has securely laid the foundations and much of the superstructure of a rational cosmogony. But there will always remain "the immeasurable magnitude of the undiscovered" to humble our pride; and ever upward progress, we trust, in our knowledge of the wondrous universe, will not lead us to imagine that we have "solved the universe."

[2] The Earth's mass being only 1/330,000 that of the Sun, is here neglected.

Device for Starting and Stopping Machine Tools

Machine tools and small machines are usually started and stopped by means of the mechanism shown in Fig. 1. The belt which transmits power

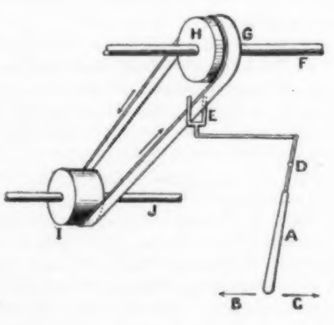


Fig. 1.

from the drum I on the general driving shaft J to the pulley G, keyed to the shaft of the machine F, is shifted to the pulley G from the loose pulley H, and conversely, by means of the fork E, attached to the short arm of the lever A, which turns on the pivot D. The arrows B and C indicate the directions in which the long arm of the lever is moved to start and stop the machine, respectively. The long wooden lever, the lower end of which must be moved through a considerable distance, occupies much space and is often in the way.

A far more convenient and compact arrangement in which the lever is suppressed and the machine is started and stopped by pulling a chain is shown in Fig. 2, and its details and operation are indicated in the diagram (Fig. 3), which, with the description of the device, are taken from *La Nature*. The fork which shifts the belt is attached to a horizontal slide carrying two vertical projections C. A symmetrical triangular cam B can slide along the same line, but to a very limited extent. The extreme right-hand positions of the slide and cam are indicated by continuous lines in the diagram (Fig. 3). By pulling a cord attached to the vertical sliding piece G the plummet A of a pendulum suspended from the top of the piece G is caused to descend between the cam B and the left-hand projection of the horizontal slide C. As the cam cannot move farther toward the right the slide C is forced toward the left by the pressure of the plummet, and the belt is thus shifted by the fork

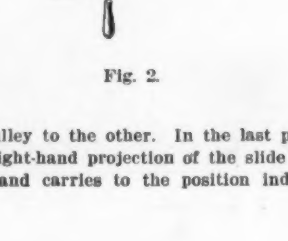


Fig. 2.

from one pulley to the other. In the last part of its course the right-hand projection of the slide C strikes the cam B and carries to the position indicated by the dotted lines, so that the slide and cam are left in their extreme left-hand positions, ready to shift the belt in the opposite direction at the next pull of

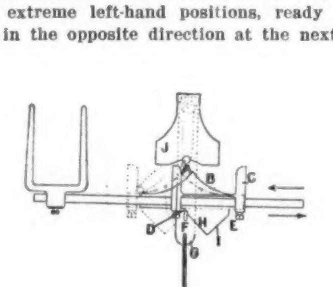
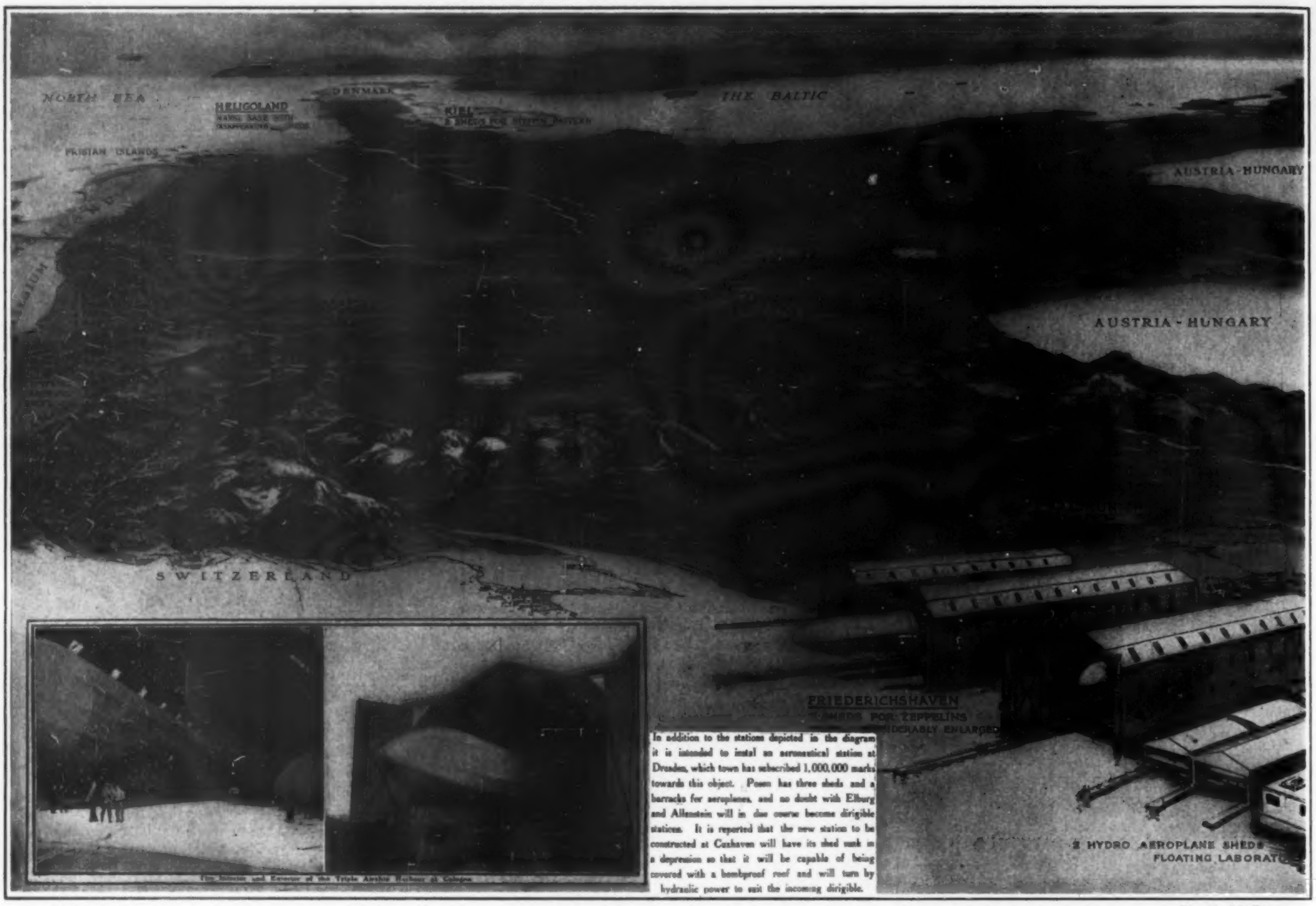


Fig. 3.

the chain. When the chain is released the vertical slide G is raised to its initial position by a spring, and the plummet is guided to its initial position by the curved lower edge of the fixed piece J. The horizontal slide C is locked in its extreme positions by the pin F which is attached to the vertical slide G and is drawn by the lifting spring into the notch D in the right-hand position, and into the notch E in the left-hand position of the slide.

If the chain is carelessly pulled part way down and then released, the pin F, in rising, strikes one of the inclined sides H and I of a cam attached to the bottom of the slide C and thus drives the slide to one of its extreme positions.



By courtesy of the Sphere. Drawn by John Duncan.

Over the Plain in Germany, Flying Stations Are Arising in Considerable Numbers. This Map Shows the Principal Stations Which Can Accommodate Zeppelin Dirigibles. In Addition to the Stations Shown, Two More Are Under Construction, One at Cuxhaven, the Other at Dantzig. Each Airship Is a Floating Wireless Station, Capable of Communicating With Stations on the Ground at Distances of 200 to 300 Miles.

Sea and Air Command*

Germany's New Policy in Its Relation to the British Naval Supremacy

In order to understand the newest development in armament policy in Germany, one outstanding fact must be borne in mind. Though the naval expenditure of Germany has risen since Grand Admiral von Tirpitz became Marine Minister in 1897 from $14,545,625 to upward of $115,000,000, and though her relative strength in comparison with other Continental fleets has greatly improved, the naval predominance of Great Britain in Europe to-day is greater than it was before the passage of the first of the Navy Acts in 1898. Ample proof of this statement will be given later on in this article.

Confronted by these facts, the German naval authorities have now adopted a fresh policy; by the development of the new aerial arm—airships and hydro-aeroplanes—they hope to turn the scales in their favor. Germany possesses already about twenty large airships and over a dozen "docks" of a permanent character, apart from private ships and "docks" subsidized by the Government and available for naval and military use, and it is now proposed to increase the number of aerial dreadnoughts to forty, and to build many more "docks." Cuxhaven, 300 miles from England, is to become a great airship station, with revolving sheds so as to enable the vessels to be launched whatever the direction of the wind, and to set forth, armed with quick-firing guns and provided with explosives, on missions of reconnaissance over the British arsenals and the bases where British squadrons and flotillas are being prepared for action. British naval strategy is to be robbed of secrecy, and secrecy in preparation is of the essence of successful strategy. This the Admiralstab in Berlin fully realizes.

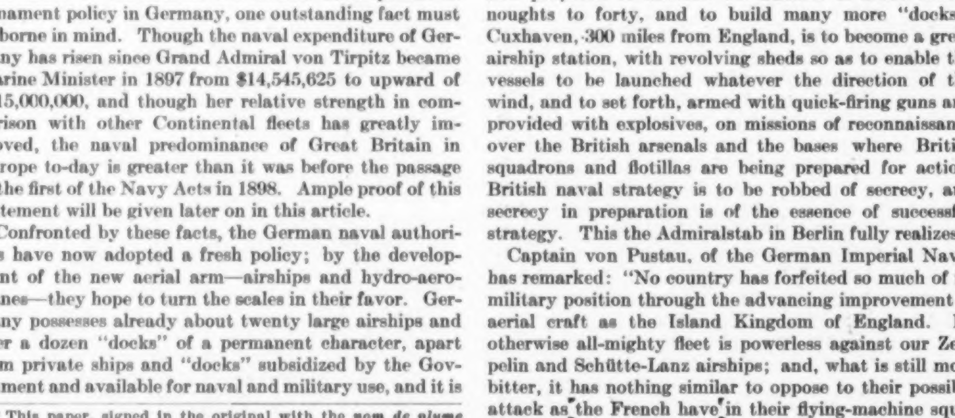
Captain von Pustau, of the German Imperial Navy, has remarked: "No country has forfeited so much of its military position through the advancing improvement of aerial craft as the Island Kingdom of England. Its otherwise all-mighty fleet is powerless against our Zeppelin and Schütte-Lanz airships; and, what is still more bitter, it has nothing similar to oppose to their possible attack as the French have in their flying-machine squadrons."

Sea-power is costly, while air-power is cheap; for the cost of a single dreadnought of the sea, a dozen dreadnoughts of the air, each with a revolving shed of the latest type, can be constructed. German expert opinion believes that by command of the air Germany can neutralize our superiority on the sea, besides unnerving the civil population and thus embarrassing the Government by cruising over these islands—high above the reach of artillery—and dropping bombs. This is the confessed policy of Germany, and we have not a single long-range airship by which we (the British) can take the only effective defensive action—the strong offensive. The cause of our present undefended state is a mystery. The highest experts at the Admiralty decided as long ago as 1908 that we should have airships, and one was commenced. It was wrecked, and nothing more has been done, though everything which has since occurred has confirmed the wisdom of the decision of five years ago. We have lost the command of the air owing to this delay.

The course of recent events is particularly interesting and significant. Last year a new Navy Act was passed by the Reichstag. This measure increased the establishment of ships in accordance with a six-year schedule of shipbuilding, and made provision for an immense increase of officers and men so as to keep nearly four fifths of the German fleet always ready for immediate action. The effect of this measure, if it had been followed by no action on the part of Great Britain, would have been that the smaller German fleet, being on a higher status of commissioning, would have been at "its selected moment" on an equality with the British fleet at "its average moment," and even in some circumstances it might have possessed such a margin of superiority as to make a naval war against Great Britain not a desperate gamble, but an operation attended with insufficient risk to act as a deterrent.

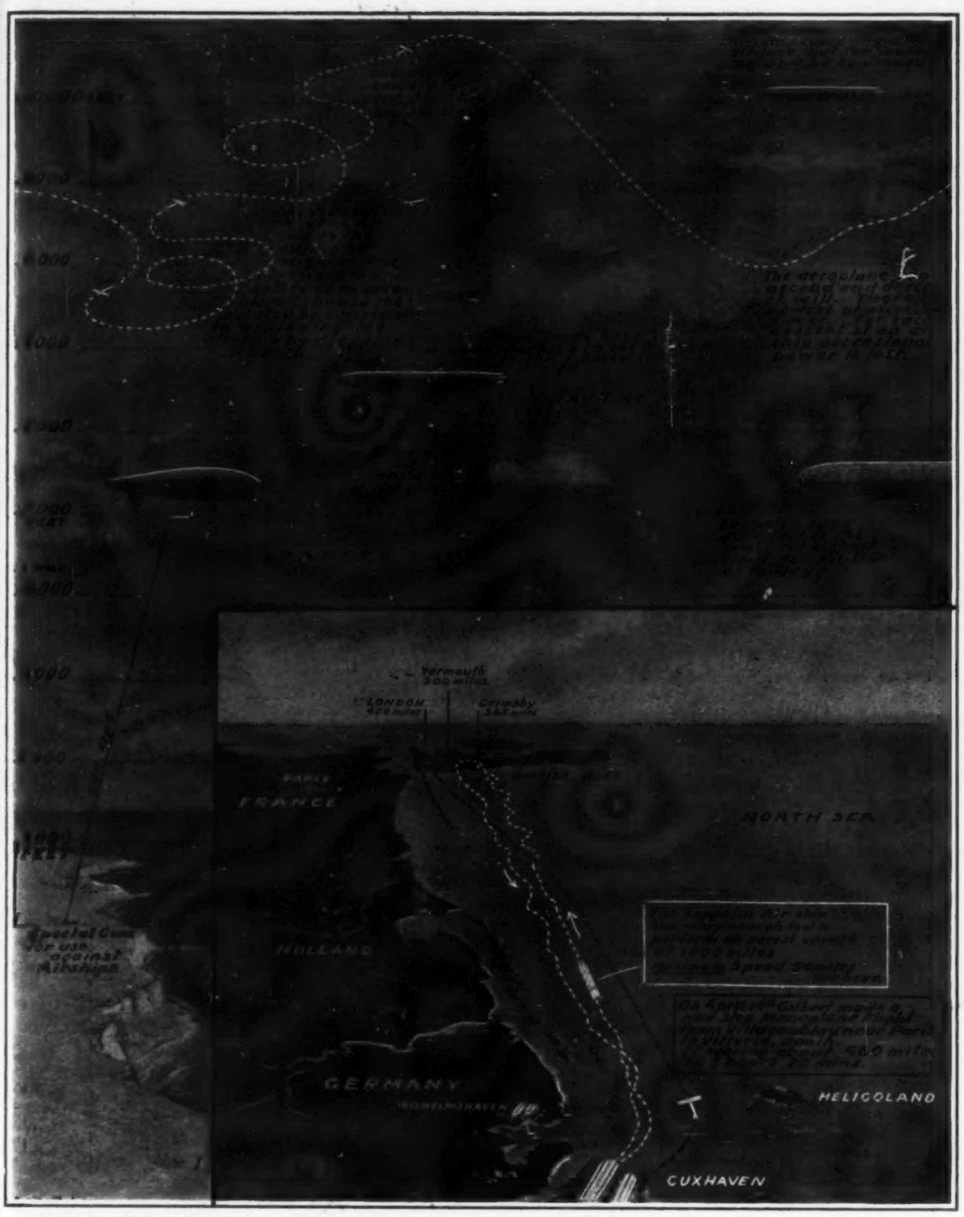
The British Admiralty replied by announcing that for every additional German armored ship laid down over and above the former law, we should build two; and they also presented Parliament with a scheme for the expansion of the *personnel*. Whatever hopes had been

* This paper, signed in the original with the *nom de plume* "Excubitor," is here reproduced from *The Fortnightly Review*.



By courtesy of the *Illustrated London News*.

Joint Action of Cavalry and Aero-corps Is Essential.



By courtesy of the *Illustrated London News.*

1. **The Ascensional Powers of Airships and Aeroplanes, and the Values of Those Powers. 2. Possibilities of Long Distance Flights by Airship and Aeroplane.**

entertained in Germany of overtaking us in the race for sea-power were thus disappointed, since the new German shipbuilding scheme was discounted on a two-keels-to-one basis.

The outlook was not encouraging to the Marineamt, and it has now decided to reply not in terms of costly sea-power, but in terms of cheap air-power. For years past, while official spokesmen in this country—and, it must be confessed, Englishmen generally—have regarded the airship as a German fad of no practical importance, tests and experiments have proceeded on the other side of the North Sea. By liberal orders and by the payment of large subventions to manufacturers and others, not only has a fleet of airships been created, but an active industry has been established capable of responding to any reasonable demand. Convinced that air-power and sea-power are inseparable and interdependent, the naval authorities have now presented to the Reichstag an aerial programme as definite and methodical in character as the ship-building programmes of successive Navy Laws. It provides for airships and hydro-aeroplanes and for aerial harbors, workshops, gasworks, and all the apparatus necessary for the development of the new arm on a large scale as well as for the necessary officers and men.

This programme on its presentation to the Reichstag was accompanied by a memorandum on air-power, which will probably become as famous as that on sea-power which was appended to the Navy Law of 1900. In this new document it is stated:

"The new weapon has for the purpose of the Navy brought a valuable extension and supplementation of tactical and strategic reconnaissance, and can also, under certain circumstances, be employed as a means of attack."

The motive underlying German aerial policy is unmistakable. It is hoped by the aid of this new arm—and particularly by the aid of long-range airships—to neutralize British naval superiority.

The dominating fact, which it is perilous for us to ignore, is that in a year or two Germany will have two squadrons of airships, heavily armed and capable of carrying considerable loads of high explosives, stationed at Cuxhaven, immediately opposite the bases of our flotillas of destroyers and submarines, and within practicable navigation distance of all our great naval ports. Moreover, she is also developing her service of hydro-aeroplanes, and is providing herself on a large scale with battleships, scouts, and mosquito craft of the air in the belief that thus she will render ineffective our superiority in battleships, scouts, and mosquito craft of the sea.

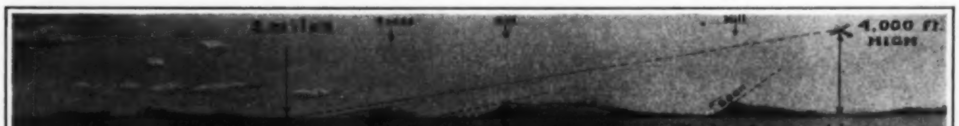
But it may be asked whether we have, as has been stated, any great naval superiority on the sea. It might sometimes be imagined from much which is written and spoken in this country that the supremacy of the sea had already passed from us. This is by no means the fact.

Keeping in mind the changes in the political conditions which have occurred in the past fifteen years, we may turn to an examination of the relative strength of the British fleet in 1898, when the first German Navy Act was passed, and in the present year after the adoption of the fifth successive measure for the expansion of the German fleet. Fortunately there is available the most authoritative material for such an examination. On May 17th, 1898, on the motion of the late Sir Charles D lke, M.P., the Admiralty issued a White Paper entitled, "Navy (Fleets of Great Britain and Foreign Countries)." At the end of March last the naval authorities published a similar return on the motion of Mr. W. H. Dickinson, M.P., showing the position on January 1st, 1913. From these two official papers the following statement has been prepared, showing the fleets of Great Britain, France, Russia, Germany, Italy, and Austria-Hungary,[1] *after omitting all battleships, coast defence ships, and armored cruisers over twenty years old from the date of launch.*

BATTLESHIPS.

	1898 Battleships.	1898 Coast Defence Ships.[3]	1913 Battleships.
Great Britain	33[2]	6[2]	62 } 92
France	21 } 32	11 } 17	21 } 30
Russia	11	6	9
Germany	16[4] } 32	6[4] } 9	36 } 58
Italy	9	—	9
Austria	7	3	13
Position of Great Britain in battleships in relation to the rest of Europe, excluding Germany	33 to 48 equals *minus* 15		62 to 52 equals *plus* 10

[1] The navy of Austria-Hungary was so insignificant in 1898 that it was not included in the Admiralty return, and for the purpose of this article reliance has been placed on the *Naval Annual* of 1898.



By courtesy of the *Illustrated London News.*

Scouting by Aeroplane and by Airship.

In 1898 the British strength in battleships and coast defence vessels as compared with France, the next greatest naval power, was in proportion of 390.5 thousand tons displacement to 226.3.

In 1913, coast defence ships having in the meantime disappeared, the British strength in battleships and battlecruisers as compared with Germany, the next greatest naval power, is in the proportion of 1,012.7 thousand tons to 530.0.

In 1916 the British predominance over Germany alone will not be so great, but under the British and Dominion programmes already announced—including the Canadian ships—it will rise to nearly two keels to one in the latest types in 1920; by that date, however, the Italian, Austrian, French and Russian fleets will have greatly gained in strength. These four countries have twenty-six battleships and battlecruisers building as compared with the British thirteen.

ARMORED CRUISERS.

	1898		1913		
Great Britain	9		34		60
France	9	16	20	26	
Russia	7		6		
Germany	3	7	9	21	
Italy	3		9		
Austria	1		3		
Position of Great Britain in armored cruisers in relation to the rest of Europe excluding Germany	9 to 20 equals *minus* 11		34 to 38 equals *minus* 4		

PROTECTED AND OTHER CRUISERS.

	1898		1913		
Great Britain	106		86		108
France	41	46	14	22	
Russia	5		8		
Germany	28	51	45	68	
Italy	16		14		
Austria-Hungary	7		9		
Position of Great Britain in protected and other cruisers in relation to the rest of Europe, excluding Germany	106 to 69 equals *plus* 37		86 to 45 equals *plus* 41		

DESTROYERS AND TORPEDO BOATS.[5]

	1898		1913		
Great Britain	148		300		661
France	211	385	239	361	
Russia	174		122		
Germany	113	322	205	377	
Italy	142		100		
Austria-Hungary	67		72		
Position of Great Britain in destroyers and torpedo boats in relation to the rest of Europe, excluding Germany	148 to 594 equals *minus* 346		300 to 533 equals *minus* 233		

SUBMARINES.

	1898	1913		
Great Britain	—	64		154
France	—	61	90	
Russia	—	29		
Germany	—	18	36	
Italy	—	12		
Austria-Hungary	—	6		

These tables give a bird's-eye view of the great European navies at the date when the first German Navy Act was passed and in the year succeeding the adoption of the fifth successive measure of expansion.

It is true that Germany possesses to-day rather more than twice as many battleships and armored cruisers as she possessed fifteen years ago, and that they are far more powerful; it is also true that she has added considerably to her strength in protected cruisers and in above-water torpedo craft; it is also true that whereas her fleet was one of the weakest in Europe in 1898, it is now the second strongest. But it is also true that the actual strength of the British navy has, as a result of German action, been so increased that even to-day it is twice as strong in ships as that of Germany, with a *personnel* of 139,000 as compared with 66,000.

The movement which Germany has financed at such colossal cost has placed her in the position of the second greatest naval power in the whole world, but it has also put such pressure upon the British people that to-day, in relation to all the other powers of Europe, Germany only excepted, the British navy occupies a position of supremacy which it has not occupied since the years immediately following upon the battle of Trafalgar.[6]

Nor does this complete the picture. Germany's position is not improving in contrast with the accumulated strength available for the defence of British interests. Grand Admiral von Tirpitz has gathered round him a great number of writers and speakers who handle with something less than the highest political skill the mass of information on foreign affairs and naval matters which issues from the Press Bureau of the German Admiralty. These naval enthusiasts, led by the German Minister of Marine, remind one of a familiar country scene. An inexperienced and rather excited drover is endeavoring to take to market a large number of cattle, and he is assisted by a group of imperfectly trained dogs. These animals are very intent upon pleasing their master, and they bark and show their teeth to such an extent that they frighten the cattle and create a scene of confusion which lands the drover into difficulties with which he cannot cope. This is a parable. The people of the British Isles are the cattle, Admiral von Tirpitz is the drover, and the dogs are the German journalists and Navy League lecturers.

In creating the naval movement in Germany, so much noise has been made, so much dust thrown up, and such violent animosity excited, that not merely have the people of the United Kingdom been frightened into taking precautions which have resulted in the relative position of the British fleet in relation to the old-established fleets of the Continent being maintained on a higher standard than before, but the peoples of the oversea dominions have been reminded of the fact that their every interest depends upon the maintenance of British sea-power, and they have been compelled to take their stand beside the mother country. When Grand Admiral von Tirpitz began his work of naval expansion in Germany, he was faced by the British fleet in isolation; to-day he is faced by an immensely stronger British fleet plus a quota of ships provoked by the Dominions. Nor is this all. The shouting and barking has made it seem desirable to France and Russia to bury the old quarrels with England; and thus not only has the German Marine Minister consolidated the British Empire, but he has forced England, France, and Russia into an *entente*, and now his colleague, the Minister of War, through the agency of the new German Army Bill, is making firmer and stronger the bonds which unite these three European powers and those other bonds between Great Britain and the Dominions overseas.

These have been the results of the armament movement in Germany. An island kingdom and the center of a maritime empire, we are less concerned than others with the amazing development of the German army. But the combined naval and military movement has produced its inevitable result upon the British proposals for shipbuilding in future years.

This is a story which German publicists might study with profit. One of the issues at the general election in the United Kingdom in 1906 was the scale upon which we should maintain the navy and army. Sir Henry Campbell-Bannerman gave his party a decisive lead in favor of retrenchment and reform. One of the cries raised by the Liberals was that the Unionist party had been profligate in its expenditure on the navy and the army, and particularly upon the former. Sir Henry Campbell-Bannerman was a conspicuously honest man—he preached what he practised. Believing that if England gave the lead to Europe and the world in the limitation of naval armaments other countries would follow her example, he abandoned the Cawdor programme, which forecasted the construction of four large armored ships annually and other vessels in adequate proportion. In 1906 only three large armored ships were laid down, the keel of not a single cruiser was placed in position, and only two destroyers were begun. In the following year the same number of big ships were authorized, together with only one small cruiser and five destroyers. Then, in the spring of 1908, the Admiralty submitted to the House of Commons a programme of only two dreadnoughts, with six small cruisers and sixteen destroyers. In the first three years of Liberal administration in this country only eight large armored ships, seven small cruisers, and twenty-three destroyers were laid down.

How did Germany respond to this well-meant, but perhaps quixotic, action on the part of the British Government? During these three years she began ten large large ships—two more than England—the same number of small cruisers, and thirteen more destroyers, and great additions were made to her *personnel*, while that of England was reduced. She did, however, more than this. Believing that the Liberal party was more intent upon a costly programme of social reform than upon national security, the German Government introduced in 1908 a new German Navy Law, supplementing the one of 1906 adopted immediately the Liberals in this country came into power. This measure carried into effect for a period of four years the very Cawdor programme which Sir Henry Campbell-Bannerman, in his keen desire for naval economy, had abandoned as being excessive even for the greatest naval power. This was Germany's response, not to a promise of retrenchment but to an actual and almost dangerous reduction of the British programme in three successive years.

The moral which British statesmen were bound to draw from such action was unmistakable, and in the following naval programme an effort was made to readjust the balance. Eight dreadnoughts were laid down, together with six small cruisers, twenty destroyers, and a number of submarines. Germany was outmanœuvred. In the succeeding three years the British Government began fourteen more dreadnoughts to ten commenced by Germany, and, in addition, they laid down seventeen small cruisers to Germany's six, and sixty destroyers to Germany's thirty-six. The reply which was made from Downing Street to the German attempt to overtake us in the construction of ships of the latest types was thus immediate and impressive.

Then Mr. Churchill came upon the scene in succession to Mr. McKenna, who had shown the highest nerve and statesmanship as First Lord of the Admiralty when Germany's refusal to limit her naval armaments was seen to be beyond doubt, and the time came to readjust the balance of naval strength which Germany, taking advantage of the attitude of the Liberal Party toward armaments, had endeavored to turn against England. Mr. Churchill decided to adopt a new method in the endeavor to bring the rivalry in naval armament to an end. In the speech with which he introduced his first navy estimates in March, 1912, he laid down specific standards of naval strength, which may be thus summarized:

(*a*) A 60 per cent superiority in vessels of the dreadnought type over the German navy on the basis of the then existing Fleet Law "with other and higher standards for smaller vessels." He announced that "If Germany were to adhere to her existing law, we believe that standard would, in the absence of any unexpected development in other countries, continue to be a convenient guide for the next four or five years so far as this capital class of vessel is concerned." Mr. Churchill, in making this announcement, carefully guarded himself against misrepresentation, pointing out that "every addition which Germany makes or may make to the new ships she lays down each year must accelerate the decline in the relative fighting value of our pre-dreadnoughts, and therefore requires special measures on our part."

(*b*) "If we are now," Mr. Churchill added, "as it would seem, and I fear is certain, to be confronted with an addition of two ships to the German construction in the next six years—two dreadnoughts—two ships spread over six years, we should propose to meet that addition on a higher ratio of superiority by laying down four ships in the same period, spreading them, however, conveniently over the six years so as to secure the greatest evenness in our finances."

The Admiralty, on the basis of this double standard, forecasted alternative programmes for six years—the first if no new Fleet Law were passed in Germany, and the second if a new Fleet Law were adopted. New naval legislation was, as a matter of fact, passed in Germany two months later, and we are therefore only concerned with the second alternative programme, namely, of twenty-five British ships—in the years 1912 to 1917—to the fourteen German ships provided under her amended Law of 1912.

In making this forecast of British policy, Mr. Churchill definitely stated that:

"Any retardation or reduction in German construction within certain limits will be promptly followed here, as soon as it is apparent, by large and fully proportionate reduction. . . .

"I have to say 'within certain limits,' because, of course, both Great Britain and Germany have to consider, among other things, the building of other powers, though the lead of both those countries is at present very considerable over any other power besides each other."

In order that there might be no misunderstanding of the offer made by the Admiralty, Mr. Churchill explained exactly how this offer would be carried out if it were accepted by Germany for the present year—that is, for 1913–14. He proposed to drop five British dreadnoughts if Germany dropped three. This offer was not accepted. It was interpreted apparently as a sign not of conscious strength, but of increasing weakness.

Nevertheless, with undaunted hopes Mr. Churchill made the offer in even more specific terms in his recent speech when introducing the navy estimates of the present year. Elaborating the forecast of British construction in the light of fuller knowledge of the naval situation, he explained that the policy of the Admiralty was as follows:

(*a*) It is intended to construct twenty-five British ships

[2] Excluding two battleships and one coast defense ship with muzzle-loading guns, and therefore practically useless, as all contemporary ships in other fleets carried breech-loaders.

[3] No coast defense ships have since been built, and they are now useless.

[4] The German battleships were small, but they were very heavily armored and with a considerable armament; the coast defense ships were also small vessels, but each carried a 12-inch gun.

[5] Most of the foreign torpedo boats were small in 1898, while fifty of the British vessels were destroyers of the then new type.

[6] This predominance will not continue if the programmes of the Triple Allies are realised in the time anticipated, and the British margins of safety in the principal strategical theaters as against these Powers will be somewhat narrow five or six years hence; but the predominance to-day is undoubted.

to Germany's fourteen, a ratio of eighteen to ten. "The difference between these programmes and a standard of construction of two keels to one over the whole period of these six years amounts," Mr. Churchill pointed out, "to only three ships."

(*b*) The ship given by the Federated Malay States and the three vessels to be presented by Canada, together with the battle-cruiser "Australia," built at the charge of the Commonwealth Government, will be regarded as additional to the British programme—"That," he added, "being the specific condition on which they were given and accepted."

(*c*) Two ships will be added to the British total of twenty-five "for every extra vessel laid down by Germany."

(*d*) Additional to this total, the First Lord finally declared, "will be any ships which we may have to build in consequence of new naval developments in the Mediterranean."

The First Lord again offered that if Germany would not lay down her fewer number of ships in any year, we would abandon our larger number. Ships in hand under former programmes would, of course, continue to advance to completion, but for one year there would be a "holiday" as regards the laying of new keels. In other words, if the proposal were adopted for the next financial year—1914–15—we should abandon our four capital ships to the two of Germany, and so on in the various classes. The scheme would not interfere with progress upon ships of earlier programmes under construction, but instead of England beginning further new vessels, representing a capital outlay of £14,000,000 or £15,000,000, and Germany a programme of £7,000,000 or £8,000,000, both countries would keep their money in their exchequers.

It might have been imagined, and Mr. Churchill was justified in thinking, that at a moment when Germany was facing a German Army Bill involving a capital outlay of £52,000,000, with a continuing charge of £9,500,000 annually, she would have welcomed such a respite, particularly in view of the manner in which the British fleet will, under the new Imperial *régime*, steadily increase its lead over her in the years immediately ahead. As Mr. Churchill has already explained to the House of Commons, comparisons of battle strength must now be made on a threefold basis, since "the difference between the super-dreadnoughts, with their 13.5-inch or heavier guns, and the dreadnoughts are no less great than those between the dreadnoughts and the pre-dreadnoughts." The First Lord added:

"Surveying, then, these three classes, we find that our tail of pre-dreadnoughts is enormously preponderant, but growing old; our middle piece comprises fourteen dreadnoughts, sixteen if the "Australia" and "New Zealand" are counted, eighteen if the "Lord Nelson" and "Agamemnon" are counted, against eleven comparable German ships.

"Our head, which consists of twenty super-dreadnoughts built and building, or twenty-one including the "Malaya," or twenty-four if the Canadian battleships are added, would be measured against a comparable German construction at present in view of twelve super-dreadnoughts.

"If to these totals were added on both sides the remaining ships forecasted in the programmes which I indicated last year—namely, twenty-one to the British total and twelve to the German total—we arrive at the position in 1920 of forty-one British super-dreadnoughts built and building, or forty-five if the Canadian and Malayan ships are included, against twenty-four German super-dreadnoughts, or a preponderance, in by far the most powerful class of vessel, which approaches two keels to one.

"Even at that date our superiority in pre-dreadnoughts will not have wholly ceased to count, but the House will see that, as it gradually passes away, provision has been made in the Admiralty programme, which I announced to Parliament last year, for counterbalancing what I may describe as the growing obsolescence of our once powerful tail by the increasing preponderance of our still more powerful head."

The naval scales, owing to the adoption of a higher British standard of construction and to the assistance of the Dominions, is turning not in favor of, but against, Germany.

And yet Germany refused—so far as can be judged from the German press—this sporting offer. She not only did this. Immediately an aerial programme, involving an expenditure of £2,500,000,[7] was produced as an extension of her naval programme. It is held by German naval officers that by obtaining command of the air, Britain's command of the sea can be neutralized. With an increasing weakness in super-dreadnoughts as against the British Empire, Germany is now turning to the construction of aerial dreadnoughts—ships of great speed, comparatively heavy gun-power, and devastating, destructive capacity owing to the loads of explosives which they can carry.

From the moment that Germany or any other nation secures command of the air, Britain ceases to be an island. This is a very disturbing fact. The British people cannot permit their geographical advantages to be taken from them. High-angle guns and shell-proof magazines, after the heart of Col. Seely, are petty measures; an offensive policy, and not the weak defence of a minor European State, must be adopted. Our aerial policy must correspond to our naval policy. It has not been the custom for the British navy to permit an enemy to come to these islands and fight; it has been our policy that whatever battles have to be fought shall be fought on the enemy's coast. Consequently for hundreds of years the peoples of these islands have not known intimately the meaning of war. Their battles have been won far away. But now airships will change this favorable condition unless we take appropriate and decisive action.

As the Admiralty once explained in a memorandum on seapower: "The traditional *role* of the British navy is not to act on the defensive, but to prepare to attack the force which threatens—in other words, to assume the offensive." This is the policy of safety which we have always adopted except on one occasion, when, acting on the defensive, England kept her ships in harbor, unrigged and unmanned, with the result that the Dutch came up the Medway and burnt the British ships-of-war at their moorings. As we have claimed supremacy on the sea, so if our naval expenditure is not so be wasted, to greater or less extent as the aerial arm of Germany develops, we must at all cost create an air fleet of corresponding size. We must, as Mr. Churchill has admitted, provide ourselves with "long-range airships" like those which Germany has built and is continuing to build. These ships are dreadnoughts of the air, with guns for offensive and defensive action in the cars underneath and on the platforms above. They have a radius of action not greatly inferior to the best of our battleships, and they have more than twice the speed. They can spy out the disposition of our squadrons and flotillas, and thus handicap our admirals, since secrecy is of the essence of successful strategy. They can cruise over our naval bases, our arsenals, and our magazines, sending back intelligence by wireless telegraphy, and they can carry great quantities of explosives with which to spread disaster among us. The peril of the airship is admitted. It is no reply to provide a few high-angle guns, to distribute ammunition in many magazines instead of a few, or to adopt other measures of defensive weakness. We must build a fleet of airships of our own, and the work must be undertaken at once.

Germany has so encouraged this particular industry that she can now construct and equip ten or twelve a year; we in this country have scoffed at the airship, and it is not certain, so backward is the industry here, that we can build a single one in a year, and it is certain that many will prove failures, and the foundation for other failures before a successful type is evolved. We have to begin very much where Count Zeppelin began in 1897; we may take less time in reaching the stage which Germany has now reached, but we are at present at a serious disadvantage. Germany has four or five firms which have dearly bought experience; we have none, unless it be Messrs. Vickers, Ltd., who may have plumbed some secrets in building the unfortunate "May Fly"—secrets which they have been unable to use.

We cannot reply to the aerial danger by developing our naval or military strength, but we must take the offensive in the air, threatening with our superior airships, in numbers proportionate to our naval strength, any potential enemy. We are now open to attack by Germany, and we must lose no time in placing ourselves in a position to retaliate. When we have asserted—as we can assert in time if we have the will, energy, and determination—our power in the air, we probably shall find that Germany will welcome a "naval holiday." At present she believes that she holds the trump card, and therefore, defeated in the struggle for the trident of Neptune, she is devoting every effort to seize and use for her own ends the command of the air in order to neutralize our naval superiority.

Leeway there is to make up, but if instant action is taken there is no reason why we should not repeat the triumph of the submarine. We awaited developments, and then at last determined on action. A little over ten years ago we had no submarines, as we have no long-range airships to-day, while France had large flotillas; as soon as the decision to create flotillas was reached, British naval officers and British firms responded with a will, and now we have a larger number of effective submarines than any other power, and they are more efficient. Again an emergency has arisen, and if immediate steps are taken there is no reason why we should not make as secure our command of the air as we are making secure our command of the sea, convinced that the future will show that aerial power and naval power are interdependent and inseparable. The essential point is that we must adopt in aerial matters our well-tried policy in naval matters—the bold offensive. Our airships, like our seaships, must be able to carry war to the enemy's frontiers and thus free us from its horrors. This is the only policy compatible with safety, and to that policy we must now bend all our splendid industrial and scientific resources if we are not to incur the risk of our naval supremacy passing from us.

7 Apart from a sum of over £4,000,000 to be spent on the development of the aerial services of the Army.

The Photosynthesis of Nitrogen Compounds

It has been known for several years that the synthesis of carbohydrates (sugar) by plants under the influence of light can be imitated, in a measure at least, in the laboratory. Instead of sunlight, however, it is necessary to use the silent electric discharge. This substitution is not unnatural when we bear in mind that in nature the green substance of the leaves (chlorophyl) acts as an intermediary, transforming the chemically less active portions of the sun's light into a form of energy possessing greater chemical activity. In the laboratory experiment no such transformer of radiant energy is present, hence it becomes necessary to employ energy in a form directly "assimilable" by the reagents.

We read now in *Umschau* that Prof. W. Löb has succeeded in synthesising under the action of the silent discharge nitrogeneous bodies also, thus taking the first step towards the experimental realization of nature's manufacture of proteids.

It was shown ten years ago by Losanowitsch and Jovitschitsch that carbon monoxide and ammonia can be united to formamide, and quite recently Berthelot and Gaudechon have shown that this reaction can be brought about by the action of ultra-violet light from the quartz mercury-vapor lamp.

Now it is found that the vapor of an aqueous solution of formamide ($HCONH_2$) undergoes a peculiar change under the influence of the silent electric discharge. Two molecules of the substance, reacting with one molecule of water, lose one molecule of hydrogen and form one molecule of ammonium oxamate,

$$2HCONH_2+H_2O=\begin{array}{c}CONH_2+H_2\\ |\\ COONH_4\\ \text{Ammonium}\\ \text{Oxamate.}\end{array}+H_2$$

Under the influence of the silent discharge the reaction then proceeds further,

$$\begin{array}{c}CONH_2\\ |\\ COONH_4\end{array}+2H_2=\begin{array}{c}CH_2NH_2\\ |\\ COONH_4\\ \text{Ammonium}\\ \text{Salt of glycocoll.}\end{array}+H_2O$$

The resulting body, the ammonium salt of glycocoll, may be regarded as the first step in the formation of the proteids, which are built up of many molecules of the type of glycocoll united together. What is more, after the facts just mentioned had been established, the experiment naturally suggested itself of starting out directly from ammonia and carbon monoxide. And, in fact, under the influence of the silent discharge, these gave glycocoll. The use of carbon monoxide in place of the carbon dioxide which forms the food of plants in nature is merely a matter of convenience. In the natural assimilation of CO_2 it is probably first reduced to the monoxide stage.

Mount Carstensz, the highest known summit of the Snowy Range of Western New Guinea, has just been ascended for the first time by Dr. A. F. R. Wollaston, an Englishman, and Lieut. van de Water, of the Dutch army. The height of this peak is supposed to be about 16,000 feet.

Volume of Traffic and Density of Population

It is evident *a priori* that there must be a relation between the volume of urban traffic and the population. What this relation is has been shown by observations collected by H. Parodi and presented by him at a joint meeting of the Institution of Electrical Engineers and the Société Internationale des Electriciens, at Paris. When the logarithms of the receipts by street railway companies are plotted as ordinates, and the population as abscissæ, curves are obtained which are nearly straight lines, and whose equation is log (receipts) = 2 log (population) + constant. In other words, the traffic is proportional to the square of the population. The question naturally arises why the law should take this form. We may say that the number of people traveling is in the first place proportional to the population, and perhaps we may surmise that, secondly, the number of trips made by each person are also proportional to the population. Hence the product, number of people traveling × trips made by each, which gives the total number of trips made, is proportional to the square of the population. Whether this argument be correct or not, its conclusion agrees with the observed facts.

Against the Sun

Spiral Twists in Nature

By A. H. Kennedy

[*The article here reproduced contains a number of interesting suggestions, though the reader may not be disposed to follow the author in all his conclusions.*—EDITOR.]

WHEN I was a boy on my father's farm in northern Ohio we used to cut stove wood with a sawing machine driven by horse power. One day, the tumbling shaft that transmitted the power to the gears that operated the saw, twisted off. This shaft was made of ironwood, a small timber that was remarkable for its toughness. The woodsmen used it for handspikes and wedges, on account of its hardness and strength. Like many forest trees, it grows in a twist. I noticed that this tumbling shaft untwisted in transmitting the power, and reasoned that if it had twisted the other way, it would have been much stronger; so we hunted the woods over to find an ironwood that twisted the other way, but failed to find one. Had we found one, it would have made a stronger shaft, as twisting with the torque it would have tightened up the grain of the timber instead of loosening it. The question arose in my mind as to the cause of this universal twist in timber mostly in one direction. Our hired man proposed that we change ends with the stick. This experiment resulted in the same way as inverting the letter "S."

Again this feature of the general twist in timber was brought to my mind when splitting fence rails. Hardly a log of oak, hickory, or chestnut was split that did not show more or less twist. In fact, we selected the straightest grained timber we could find as being more easily worked, and making better fence rails. Rails cut from winding timber made an unstable fence. Here, again, I was challenged to discover the mysterious power that gave to timber its twist. I could not solve the mystery.

Once more the fact of the twist in timber was called to my mind by a carpenter who was building an addition to my father's house. He dressed the rough boards in the old way by means of a jack plane, and finished with a smoothing plane. I noticed that he changed ends with some of the boards. When asked why he did so, he remarked that it enabled him to plane with the grain rather than against it on the edge next to him; that the most of timber had a twist, generally in the same direction, and that boards sawed from the log near the heart had the grain in opposite directions on opposite edges of the board. What operator of a modern planing machine has not noticed that a wide board that is cut near the heart of the log, when run through the machine, planes with the grain on the left edge, and against the grain on the right.

Is this universal twist in timber due to some fortuitous circumstance, or is it the result of some unseen force that has been silently at work throughout the life of the tree? Or has this silent influence been working through the dim ages of the past, developing the torque in the trees, and implanting it in their seed after them from generation to generation? So that the acorn gets a torque-nature established, bearing seed after its kind.

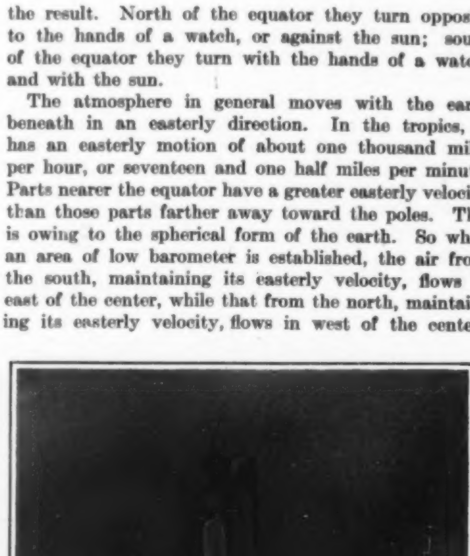
Again, years after, this timber twist was brought to my attention in the forests of northern Michigan. I chanced to meet a crew of timber hewers who were squaring long timbers from the trunks of the rock elm. One of the hewers remarked that a left-handed hewer could beat a right-handed hewer every time, and no other hewer challenged his word. I inquired the reason, and he replied that it was altogether on account of the general twist in timber. The left-handed hewer had the grain with him, while the right-handed hewer had the grain against him. My attention was called to the general twist in the various trees of that locality, the hemlocks, cedars, pines, etc., and again I essayed the hypothesis that had dropped from my mind so many years ago. I caught a glimpse of a far-reaching, mysterious law that waves its subtle wand over every department of Nature. The tree, the vine, the cyclone, the sailing bird, the water spout, the spiral-shaped nebulæ, the race course, and the games of my childhood. I woke from my dream, and forgot all about the hypothesis until it was brought impressively back to my mind by the antics of a dozen mice playing on a whirligig treadmill in the show window of a drug store. A wheel of heavy cardboard, about fifteen inches in diameter, is pivoted on a vertical axis. Turn a dozen mice loose in the cage, and in a short time they will all climb upon the wheel, spinning it around as fast as they can run; generally against the sun. If one falls off, he runs up the support and down the exit and joins again in the fruitless Sisyphean race. Here, again, I was challenged by this curious exhibition of human ingenuity and animal instinct to fathom this wonderful mystery. Everything that had a twist or a twisting motion fascinated me until I could resist no longer the temptation to essay a possible hypothesis of this wonderful mystery.

If from some meteorological cause an area of low barometer is formed on the western plains, the air in all the surrounding regions flows with more or less velocity toward this area, seeking to establish equilibrium. If condensation takes place, as usually happens, the velocity is accelerated, and a cyclone or a tornado is

Chasing His Tail Against the Sun.

the result. North of the equator they turn opposite to the hands of a watch, or against the sun; south of the equator they turn with the hands of a watch, and with the sun.

The atmosphere in general moves with the earth beneath in an easterly direction. In the tropics, it has an easterly motion of about one thousand miles per hour, or seventeen and one half miles per minute. Parts nearer the equator have a greater easterly velocity than those parts farther away toward the poles. This is owing to the spherical form of the earth. So when an area of low barometer is established, the air from the south, maintaining its easterly velocity, flows in east of the center, while that from the north, maintaining its easterly velocity, flows in west of the center.



Mice Dancing on Treadmill Against the Sun.

This movement of the air into opposite sides of the area of low barometer forms a vortex, and causes the cyclone sweeping over a territory of vast extent like a great millstone, or the tornado which with untold power sweeps along a path only a few rods wide. The motion north of the equator is invariably against the sun, or in a direction opposite to the hands of a watch. In the case of a tornado the condensation and rotation are so rapid and violent that a partial vacuum is probably formed, for wells are sucked dry even if the tip of the tornado's trunk but touches them.

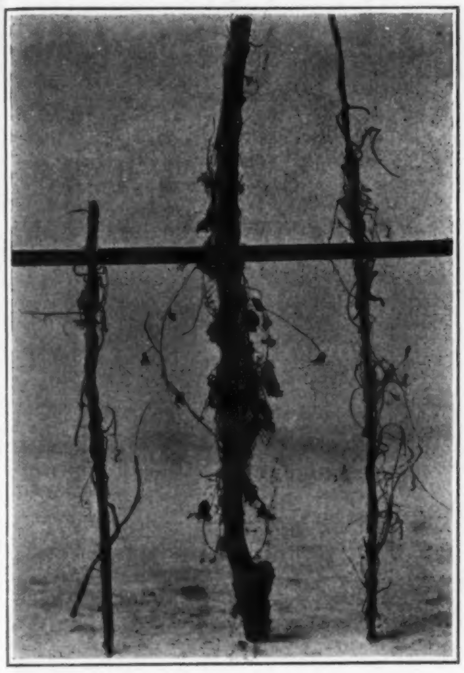
The electrical display is only a concomitant of the process; an effect and not a cause of the tornado. The wonderful electrical display is caused by the rapid condensation. The static electricity that everywhere resides on the surfaces of the invisible particles of vapor that fill the air for miles around, when concentrated into the condensed rain drops at the heart of the storm, multiplies its voltage many thousand fold. This is all the result of the geometrical relation of the surface of a sphere to its volume. The surface of a drop of water varies as the square of its diameter, while its volume varies as its cube. I mention this fact incidentally because a tornado is commonly attributed to some electrical cause.

The conditions for a tornado are:

1. A somewhat level tract of territory.
2. A sultry, still day when the air is saturated with moisture.
3. The unequal velocities of the earth's surface, and the superincumbent air toward the east.
4. An area of low barometer somewhere in this level tract of territory.

When condensation once begins, the air for miles around moves toward this center of condensation, but misses it to the right, and turns it against the sun. The tornado on water develops the water spout by drawing the water up its vacuum tube. The power displayed by a tornado is prodigious. It is easily accounted for by the fact that air at atmospheric pressure will flow into a vacuum at the enormous velocity of fifteen hundred feet per second. Thousands of tons of water are raised hundreds of feet high in the water spout. An oak is twisted off by the tornado, and carried away like a feather. A locomotive is picked up from the track, and pitched over into the adjoining field. To show the extreme delicacy of the conditions that produce the cyclone, the following experiment will suffice: Make a hole about an inch in diameter in the bottom of a wide tub or vat; plane it out like a funnel, smooth and round; set the tub so as to afford ready access to the bottom; cork up the hole in the bottom; fill the tub with water, and let it stand over night where it will be free from any jar or currents of air. Draw the cork from the bottom and presently a vortex will be formed which invariably will turn to the left against the sun. The wider the tub, the better. Drawing the cork produces, as it were, an area of low barometer toward which every particle of water moves. They all start for the center of the hole, but miss it to the right for the same reason as above cited in the case of a tornado or water spout. The delicacy of this force is incomprehensible when we consider the infinitesimal difference in the easterly velocities of the north and south sides of the tub. May we not infer from this experiment that everything that moves on the earth, in the sea, and in the air is subject to this same law? May it not have implanted some characteristic of its influence in the flora and fauna of the world?

The earth itself is a vortex resulting from the condensation of one of the sun's nebulous rings. The earth's diurnal and orbital motion came about in much the same manner as that of the cyclone or tornado. In the condensation of its nebulous mass at some point of greatest density, one half of the ring was accelerated in its orbital motion, while one half was retarded; the retarded portions losing in centrifugal force, and falling nearer the sun, and the accelerated portions gaining in centrifugal force, falling farther away from the sun. This coming together of two streams of matter from opposite directions and meeting on opposite sides of the same center, resulted in a vortex of which the diurnal motion of the earth is the present manifestation. The rings of Saturn, the spiral shaped nebulae, the sun himself, every revolving planet and star, give evidence of the same process in all the wonderful architecture of the heavens. In fact, the solar system itself is a vast vortex which was set a-spinning by the condensation of the matter of which it is composed along the sun's path around some far-off center



Climbing Plants Entwining Stems, With a Twist Against the Sun.

While the process of the evolution of a tornado lasts but a few minutes at the most, and that of a cyclone a few hours or days, the evolution of a planetary system from its primordial nebulous mist reaches back through countless aeons.

Animate nature has doubtless felt the impress of nature's hand in the operation of this law, and has written in its structure the records of changes that have been accomplished through countless generations. The vegetable kingdom is subject to this subtle power, as the following considerations will show: An oak with its wide-spreading branches and the flowing sap is in a sense a vegetable vortex. The numberless roots of the oak spread out through the soil, and gather in the moisture laden with the elements necessary for its growth. It is carried as the sap up the trunk, out by the branches to the leaves, where the chemistry of the sunlight refines and reorganizes it in its wonderful crucible for the oak's use. In the course of the oak's lifetime many tons of sap have been circulated between the center and the circumference of the oak. Were it free to revolve on its trunk as an axis, the inertia of the sap flowing from the center to the circumference should cause it to turn with the sun. This motion should be to the right, provided that all motion of sap and growth were from the center to the circumference. But since the tree cannot turn freely, its tendency is to twist the trunk. When we consider that this unseen force, infinitesimal though it be, has been acting throughout the development of every species of tree, is it any wonder that the tendency to twist is planted in their very nature, and in their seed after them?

Who has not tried to train a bean vine to twist the other way around the bean pole, to the right with the hands of a watch? The free end shoots out, and coils the other way to the left. It is under the spell of this mysterious, invisible force that has held it in its embrace since when it first took its place among the flora of the world. The morning glory, the woodbine, the hop vine and ivy are marked examples of the influence of this force. The tendency to twist and entwine around objects has become a potential characteristic implanted and interwoven into their very nature, as the result of untold ages of twisting and turning, caused by the daily torque of the earth rotating upon its axis.

Who has not watched a sailing bird as he circles around and around, rising higher and higher without a flap of wing, until he is lost to sight? Somehow he has found it easier to sail against the sun than with it.

Just across the way from my home is a large, tall ventilating chimney, where thousands of swallows make their nests every year. When nightfall comes they gather in thousands, flying about for a time, helter skelter, but finally falling into line in an immense circle, more or less well defined, with one side passing over the air shaft. Now and then a swallow drops in as though to spy out the way. When they have fully made up their minds that the day is done, they pour down the shaft in a constant stream. The ring grows thinner and thinner, until the last one gives a parting twitter to the close of day and drops in.

Schools of fish, fresh from the spawn, spin round and round, spread out into a spheroidal form, and expand into a revolving ring which turns generally against the sun.

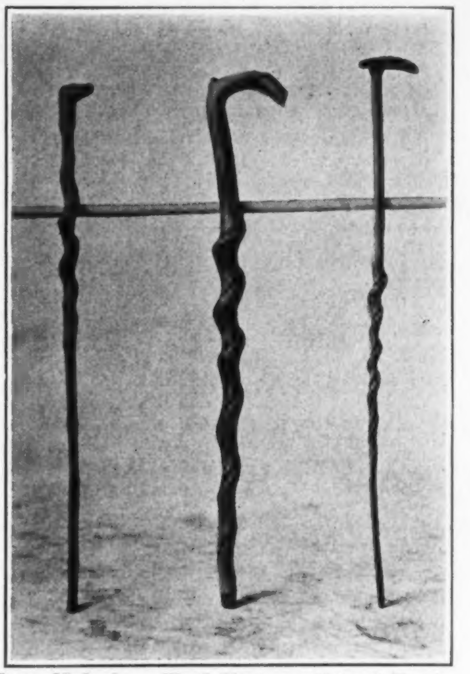
Crows frequently gather together in large numbers and form a kind of crow cyclone. This formation is called a well of crows, and rotates like the cyclone against the sun. The same conditions that aid the sailing bird to circle around and around without flap of wing help the crows as well to produce their strange formation.

The race course, since when Ben Hur drove Atair, Rigel, Antares and Aldebaran around the ancient track at Antioch, has always been against the sun. The modern automobile racetrack, built with high slopes at the curved ends, the small circular track at the circus and hippodrome, the race track at the country fair, are all examples of racing in a circle against the sun.

The games of our childhood days are many of them examples of this law of rotation to the left against the sun. In the game of "Fox and Geese," a large ring of one hundred feet in diameter is trodden out in the snow, and a number of spokes are located at equal intervals. The fox takes his place at the center, and the geese at the intersections of the spokes with the rim of the wheel. As the fox gives chase, the geese run around the rim, always to the left, against the sun. In the game of "Baseball," the runs are invariably made to the left against the sun. In the game of "Drop the Handkerchief," the running is always to the left, against the sun. Notice how perfectly natural it is to turn to the left against the sun when waltzing. The old fashioned horse-power, with its six or eight sweeps to which a span of horses was hitched, to operate a threshing machine, or a sawmill, turned to the left, against the sun. Every capstan with its several levers and sailors turning round and round, rotates to the left, against the sun. The great turbines at Niagara Falls, and the great vertical steam turbines of many thousand horse-power that generate the electric current for light and power, all spin round to the left, against the sun.

Often when one is lost in the woods, and sets out to take a bee line for camp or home, he finds himself traveling round and round in a circle of large diameter, to the left, against the sun.

It is an established custom among all peoples to turn to the right when they meet. As all known civilizations have had their origin in the northern hemisphere, may it not be that this custom owes its origin to the influence that the rotation of the earth has upon all bodies that move on its surface? Traveling in a circle when lost, and turning to the right when meeting, has been explained by supposing that the right leg is longer or stronger than the left. Herbert Spencer proposes as a reason for turning to the right when meeting, the fact that our savage ancestors carried the shield over



Canes Made from Wood Having a Natural Twist—Against the Sun.

the heart on the left arm, and wielded the spear and sword with the right. I am persuaded to believe that all these customary operations of mankind, some of the salient of which I have cited, are the result of a common cause, the effect of the revolution of the earth.

Another interesting example is the fact that the flanges on the right wheels of locomotives wear off more rapidly than those on the left, on a north and south track. Were the locomotive not reversed on each trip the wear would be the same on both the right and left flanges. The same cause that directs the air to the right of the center, as it flows into the cyclone, makes the locomotive hug the right track on both its northern and southern trips.

This tendency to twist not only manifests itself in the mechanical arts and the social pleasures and sports of mankind, but it enters the realm of the fine arts of painting, sculpture, and architecture. Thus: Fine arts are but an imitation of nature in all her varied moods and phases. If an ivy vine is chiseled or painted around a column, as it rises from the base to the capital, it entwines the column against the sun.

Every morning, my friend over the way, takes a walk down town with a cane that is a fine example of the universal twist that prevails throughout nature. He says that it was cut from his farm and that a vine grew around it when it was a sprout, and made the spiral groove that winds around it with such symmetry. My friend has several more like it cut from the same locality.

Notice that the spiral is entwined to the left like the bean vine against the sun.

What child has not watched a dog or a cat chase his tail? Round and round he goes until exhausted, usually to the left against the sun.

A stairway in a tower or monument almost invariably winds around to the left against the sun like the twist of the tree or the twining vine.

The foregoing is more than an inference, for each revolution of the earth, since i was set a spinning by the condensation of a ring of the sun, has placed its impress, little though it be, upon every department of nature.

A New Law of Vulcanization*

The Physical Chemistry of Rubber Manufacture

By Augustus O. Bourn

Strictly speaking, it is incorrect to use the term "a new law of Nature." Nature has no new laws. Her laws, so far as we can judge, have always existed and will always exist—unchangeable. By the term "a new law of Nature" we simply mean that from a series of observations of well-known facts, or of facts not before known, a law has been deduced which is new to us.

The known laws governing the chemical combination of rubber and sulphur during vulcanization have been deduced from well-known facts and are in no respect different from general laws governing chemical reactions. They may be briefly stated as follows:

1. The combination is brought about by the influence of heat.

2. The velocity of the combination increases faster than the increase of temperature and decreases correspondingly with a decrease of temperature.

3. The vulcanizing effects of a given vulcanizing temperature is the precise complement of every other vulcanizing temperature.

Even a cursory glance at these laws enables one to see that they are general laws governing chemical reactions, and also that both the second and the third law suggest the existence of another.

While it is true that the majority of chemical reactions take place with development of heat and without external aid, there is a large number requiring the aid of external energy (in the form of heat, light, pressure or electricity) to induce the reactions. The direct combination of a mixture of iron and sulphur in fine powder is a well-known example of a chemical reaction which requires the aid of heat (or pressure) in order that the combination may proceed at an appreciable rate, and seems in

* Paper read by Augustus O. Brown at the conference held at the International Rubber Exhibition, New York, September 27th, 1912.

principle to be in no wise different from the manner in which the combination of rubber and sulphur is brought about.

As the rate of this combination increases or decreases with each increase or decrease of temperature, it is most natural to ask what this rate is. It is very strange that the rate or ratio seems to have been almost entirely unknown, both to manufactures and investigators, and the more so as a knowledge of it would be of great value in conducting vulcanizing operations, and would almost seem to be the foundation of a careful investigation of the subject of vulcanization.

To ascertain by actual experiment this ratio of increase or decrease, quite a large number of experiments have been made with the same compound and with samples of uniform thickness in nearly all the well-known processes of vulcanizing with heat—in dry air—in dry air impregnated with sulphur vapor—in melted sulphur—in hot water without pressure—and in a metallic medium, both with and without pressure. No experiments were made with the steam process or in hot water under pressure, as under the most favorable circumstances several minutes must be lost each time that samples are examined. The loss of so much time would be fatal to accuracy, as many of the tests did not occupy more than a few minutes, and some not more than a few seconds. For the processes which were used, it was necessary to devise apparatus which would permit an examination of samples without appreciable loss of time.

As the known laws governing vulcanization are identical with known chemical laws, it should be stated here that these investigations were suggested by a well-known law regarding the effect of an increase or a decrease of the velocity of chemical reactions in general. This law is stated so clearly by Prof. Ostwald, one of the best-known chemical authorities, that his statement of it is given in full:

"Innumerable substances between which chemical reactions can occur can remain in contact with one another without our being able to detect such actions. The most appropriate interpretation of these facts is that in all such cases the possible chemical reactions do, as a matter of fact, take place, but to such a small extent or with such slowness that they cannot be detected in a measurable time. The following shows that this view is quite compatible with the universal experience. By time measurements of the progress of many chemical reactions, the approximate rule has been obtained that the velocity of chemical reactions is, on an average, doubled by a rise of 10 deg. Cent. (18 deg. Fahr.) in the temperature. That is to say, if a reaction at a given temperature requires, say, a quarter of an hour to reach a certain point, at a temperature of 10 deg. Cent. (18 deg. Fahr.) higher it would require only 7½ mintes, and at one 10 deg. Cent. (18 deg. Fahr.) lower 30 minutes. If the temperature is lowered 100 deg. Cent. (180 deg. Fahr.), a 2^{10} equal to 1,024 times longer period is necessary, or, in our example, about 11 days. On descending further 50 deg. Cent. (90 deg. Fahr.) or, on the whole, only the moderate amount of 150 deg. Cent. (270 deg. Fahr.), it would be a year before the reaction had proceeded so far as it had done in a quarter of an hour at the higher temperature.

The experiments referred to were first made with a compound composed of 12 pounds dry fine Para rubber, 6 pounds litharge, 6 pounds whiting, and 6 ounces sulphur, which gives a proportion of about 3 per cent of sulphur. As a result of the experiments, it was found that when the samples, containing 3 per cent of sulphur, were submitted to the ordinary dry heat air process, approximately for the times given below, physical vulcanizing effects, as nearly identical as could be perceived on a most careful examination, were obtained when the submission was made at the temperature set opposite the times:

15 seconds at 337 deg. Fahr.
23 seconds at 326 deg.
35 seconds at 315 deg.
1 minute at 304 deg.
2 minutes at 293 deg.
3½ minutes at 282 deg.
7 minutes at 271 deg.
13 minutes at 260 deg.
26½ minutes at 249 deg.
53 minutes at 238 deg.
105 minutes at 227 deg.
210 minutes at 216 deg.
420 minutes at 205 deg.
840 minutes at 194 deg.

These results seem to establish the rule that for each increase in temperature of about 11 deg. Fahr. during the vulcanizing operation, the velocity of vulcanization is doubled, and that for each decrease in temperature of about 11 deg. Fahr. the time required for vulcanization is doubled.

As direct experiment, however, carefully conducted, is more or less liable to error, and as it is somewhat difficult to judge exactly the physical degree of vulcanization of a rubber sample, the results above given may not be absolutely exact. But as they represent the average of a number of separate vulcanizations, they may be considered as accurate within the limit of experimental error.

It will be noticed that the temperatures given range only between 194 degrees and 337 degrees, and also that above 304 degrees the ratio of increase is different. Below 194 degrees the compound containing 3 per cent of sulphur does not seem to vulcanize satisfactorily by the air process. But in other processes there is no trouble whatever in effecting vulcanizations in accordance with the foregoing rule down to 161 degrees, which is the lowest temperature tried. Above 304 degrees the rate of increase is changed for all the processes, probably because at temperatures a little above 304 degrees there is a marked change in the physical constitution of sulphur, and possibly also because, as experiments tend to show, the rubber compound used is proportionately a poorer conductor of heat at the higher temperatures.

This change begins considerably lower, but is apparently slight. As is well known, sulphur when heated above 250 degrees gradually grows darker and becomes thicker, until from about 360 degrees to about 430 degrees it is so thick that it pours slowly from the vessel in which it is heated. These changes are believed to be changes in its molecular state and affect not only its physical constitution but its chemical properties. That the law varies above 304 degrees is to be expected, as the physical change in the constitution of the sulphur is attended with changes in its chemical properties

Above 304 degrees Fahr. it is somewhat difficult to determine the ratio of increase. But a few experiments seem to indicate that a change of about 25 degrees is required, in order to double the velocity of vulcanization. Between 304 and 400 degrees the time required for doubling the velocity of vulcanization may be judged from the following table showing the approximate temperatures necessary to double the velocity:

325 degrees 26 seconds.
350 degrees 13 seconds.
375 degrees 6 seconds.
400 degrees 3 seconds.

As the time required at 400 degrees was only three seconds, and as at considerably higher temperatures the time required is only the fraction of a second, it can be readily seen that it is very difficult to determine a ratio when such short periods of time are concerned.

Care was taken that the physical condition of the samples used for the experiments was as nearly identical as possible, as a variation in that condition would vary the time required for vulcanization. It was also necessary to use samples of the same age for comparison of results, as it was found that the longer they were left undisturbed at room temperature, the quicker they would vulcanize. Samples which had been kept nearly four months at that temperature required materially less time for the same degree of physical vulcanization than when they were freshly prepared.[1]

The result of these experiments naturally suggests the view not only that a properly compounded rubber vulcanizes at all temperatures, but the vulcanization commences immediately upon the compounding.

The preceding part of this paper was written in 1903. Shortly after that time experiments were made with a view of testing the truth of the proposition that vulcanization proceeds at all temperatures. Accordingly samples of Para rubber compounded with from 5 to 7 per cent of sulphur and 50 per cent of litharge, were subjected to treatment at temperatures varying from 161 to 194 deg. Fahr. in a bath of metal which fuses at about 150 deg. Fahr. The results confirmed the general rule obtained in the preceding experiments, with the exception that the time required for doubling the velocity of combination was somewhat greater for an increase of 11 deg. Fahr. in the temperature.

Samples of the same compound were then embedded in a ball of the same metal fused, which was then immediately plunged into cold water, with the result that any vulcanization resulting from short exposure to so low a temperature was negligible. The ball containing the samples was placed, February 28th, 1904, in a room whose average temperature was estimated to be about 110 to 115 deg. Fahr. September 27th, or practically seven months later, the samples were examined, and were found to be thoroughly vulcanized They are here to-day in a state of perfect preservation after the lapse of eight years, and can be examined by anyone who wishes to do so.

May 27th, 1904, samples of the same compound were embedded in a jar of flower of sulphur, which was well corked, and exposed in the same room to the same tempreature as in the case of the last preceding experiment for four months. These samples were not fully vulcanized, but an examination to-day shows them to be well vulcanized, strong and elastic. The only inference to be drawn from this fact is that the vulcanization commenced at about 110 to 115 deg. Fahr. has been completed during the eight years during which they have been exposed to an ordinary room temperature.

In February, 1912, another series of experiments along the lines of those of 1904 were commenced. Similar samples of a similar rubber compound and also samples of four different grades of rubber shoe compounds were placed in a ball of fusible metal, in a well-corked jar of sulphur, and in two tight jars, one containing a mixture of one part by weight of sulphur with five parts litharge, and the other containing a mixture of equal parts by weight of sulphur, litharge and Green Seal French Zinc. In addition there were placed in each jar samples of pure fine Para rubber, which had been peeled, as it were, from a crude biscuit, and which was, therefore, entirely free from compounds or mastication of any kind.

While the samples embedded in fusible metal were entirely free from the action of oxygen, they were also entirely free from any action of the other substances in which the other samples were embedded. The influence of those substances is very apparent, even on a casual inspection of the samples.

Of the samples inclosed in fusible metal, the compound referred to is the only one that is properly vulcanized. All the others are vulcanized very perceptibly less than those embedded in sulphur, sulphur and litharge, or in sulphur, litharge and zinc.

All of the samples embedded in sulphur were vulcanized—the samples of second and third grade uppers being over-vulcanized.

The action of litharge and sulphur as compared with the action of sulphur alone was very marked, the vulcanization of all the samples being carried much further than in the case of either of the other experiments.

The samples embedded in the mixture of sulphur, litharge and zinc were vulcanized to a greater degree than those embedded in sulphur, but less than those embedded in sulphur and litharage.

The most wonderful result of these experiments was the vulcanization of pure Para biscuit rubber. If, as is considered, vulcanization can only be effected by sulphur molecules S_8, it is obvious that at the temperature of 115 deg. Fahr. there is sufficient dissociation to produce in seven months a fair degree of vulcanization in pure virgin rubber, which is entirely free from sulphur itself, but which has simply been embedded in sulphur. Still further, at ordinary room temperature, there must be some dissociation in order to complete in eight years the sample which was deficient in vulcanization September 27th, 1904.

An analysis of the pure Para rubber, made after it had been embedded in sulphur six months, showed 0.49 per cent of combined sulphur, the sample having been subjected to the acetone method for sixteen hours, in order to remove every possible vestige of uncombined sulphur. If the rate of combination be the same for seven months as for six months, we should expect that there would be 0.5716 per cent of sulphur in the sample embedded in sulphur for that period.

The result of the embedding of pure Para rubber in the mixture of one part of sulphur and five parts of litharge by weight would seem to show that in this instance the litharge acted by promoting the dissociation of the sulphur molecule. Strictly speaking, it could not act as a carrier, as it was external to the rubber. The dissociated sulphur must then either of its own action, or by the action of the rubber, have penetrated the rubber and then combined with it.

Another important deduction to be made from the new law of vulcanization and the experiments made in accordance with it, is that the melting of sulphur has not the slightest effect in changing the rate of vulcanization, as whatever may be the time required to vulcanize a rubber compound at 227 deg. Fahr. will vulcanize in one half that time at 238 degrees and in one quarter the time at 249 degrees.

Another deduction that can safely be made is that vulcanization of rubber properly compounded proceeds at all temperatures, whether high or low. At high temperatures the compound may be vulcanized in one second or less, and at low temperatures the vulcanization may proceed so slowly as to escape our attention.

[1]This increasing ratio is substantially verified by recent experiments by Spence and Young (*Zeits. Koll.*, July, 1912), who found that a mixing containing 10 per cent. of sulphur reached saturation after an exposure of 20 hours to a temperature of 135 degrees C. (275 F.), and also after an exposure of 5 hours to a temperature of 155 degrees C. (311 F.).

The Existence of an Ultra-Neptunian Planet*

By Philip H. Ling, M.Sc.

The discoveries of the planets Uranus and Neptune were the first two steps in the outward extension of our knowledge of the solar system. The third step—the discovery of a planet still more distant—is yet to be made. There is, however, a considerable amount of evidence for the existence of such a planet, and in the present article it is proposed to give a short discussion of the arguments which have been brought forward.

It should be remarked at the outset, that visual obser-

* Reproduced from *Knowledge.*

vation will play no part in the argument; for it is almost certain that no planet exists of sufficiently large dimensions. We, therefore, have recourse to indirect methods by studying the effects which the hypothetical planet may be supposed to produce in bodies which are themselves capable of being observed.

(1) The most obvious way of doing this is by examining the perturbations of Neptune. Now the latter has a period of one hundred and sixty-five years and has only been under continuous observation since 1846—that is, for less than one half of its orbit. It is obvious that no certain conclusions can as yet be drawn from so small a portion of Neptune's path; and while the method may by useful centuries hence, it is at present too precarious.

(2) A more hopeful plan is to study the perturbations of Uranus. These are not completely explained by the attraction of Neptune, and have recently been examined almost simultaneously by Pickering[1] and by Gaillot,[2] working independently. They agree in the mean distance of the unknown planet, which is given as about fifty-two astronomical units; but Pickering finds the mass to be twice the mass of the earth, while Gaillot makes it five times; the latter also suggests a still more distant planet to be required. The smallness of the mass militates heavily against the correctness of the arguments since the effects produced must be infinitesimal.

(3) The best method of all is that derived from the orbits of comets. If we compile as complete a list as possible of the periodic comets, arranged in ascending order of period, a very striking fac becomes apparent. They are seen to fall into groups, the first of which contains those with periods ranging from 3.3 to nine years, the second those of period about thirteen, the third about thirty-three, the fourth about seventy-three, while there seems to be a fifth with period about one hundred and twenty-one years. Now each of these groups contains comets whose aphelia are approximately at he same distance as one of the planets Jupiter, Saturn, Uranus, and Neptune, while the fifth group seems to correspond to a hitherto unknown planet. There is, therefore, apparently some connection between these groups of comets and the corresponding planet, and before basing any argument on it, it is necessary to inquire more closely into the nature of the relation.

Now the most obvious explanation of the relation between comets and planets, is that known as the "capture" theory. According to this, at some previous era the comet approached so closely to the planet, that the gravitational attraction of the latter was sufficient to overpower that of the sun, but not large enough to transform the comet into a satellite. The orbit thus became a long ellipse, with one focus in the sun and the other in the position temporarily occupied by the planet; and this orbit would remain permanent in the absence of commensurability between the periods.

This appears to afford an explanation; but two difficulties, mentioned by Newcomb[3], arise. In the first place, Encke's comet has its orbit completely within that of Jupiter, and no close approach occurs; but we know that this comet probably passes through a resisting medium, which is altering the major axis, and it has been shown by Backlund[4] that "capture" within the last five thousand seven hundred years is not by any means impossible.

The second difficulty is extremely serious. The planets all move nearly in the same plane; the orbits of comets, however, are inclined to this plane at all angles, and, as a result, though the statement as to the aphelion distance above is still true, there is, in point of fact, no close approach at all. This is exemplified by Halley's comet, which, having its orbit inclined to the ecliptic at about 18 degrees, never passes near the path of Neptune, to whose group it belongs.

In discussing the difficulty, we must remark that for "capture" to take place, it is only necessary that the aphelion focus should be in the plane of the ecliptic. Since this is not the case, there must have been a secular rotation of the major axis, which had moved the aphelion from its original position. If this rotation does not exist, then the "capture" theory must be abandoned. This applies to the more distant comets, for Jupiter's group is generally acknowledged to have been "captured," and in its case the inclination is usually small.

It is interesting to notice in the orbit of Halley's comet (the only distant comet which has been very thoroughly investigated) there was a divergence of two days in 1910 between the actual and calculated times of perihelion passage, so that an unexplained rotation of the major axis certainly exists. This is not to be referred to any known mass in the solar system, while an unknown mass must necessarily be very considerably out of the plane of the ecliptic to produce the observed results.

At this point, much light is thrown on the subject by a remarkable paper by Pickering[5], which has recently appeared. If the translational motion of the solar system through space experiences any resistance from the ether, or from scattered matter, the effect will be most visible in the case of comets, owing to their small mass and large superficial area. The result will be, that the aphelia will fall behind and will tend to group themselves in a direction opposite to that of the sun's motion. Pickering shows that this actually takes place, and supposes that the divergences which are visible are to be attributed either to a motion of the absorbing medium, or to a curvature in the sun's path. Here, then, is the explanation of that secular motion of the major axis, which we have shown to be required by the "capture" theory; and the latter is, therefore, not inconsistent with the facts.

The assumption of a resisting medium naturally raises some suspicion, for there is a danger of using it as a *deus ex machina*, in the way of solving astronomical difficulties. But it certainly exists in the shape of meteoric swarms, even if the ether be itself non-resisting, and it is now fairly certain that the cause of the anomalous motion of Encke's comet is to be found in this direction. We may, therefore, conclude that if a group of comets exists outside that of Neptune, it is *a priori* evidence for the existence of a more distant planet.

Now, unfortunately, the evidence is rather meager. Grignell[6] examined twenty comets, and deduced a planet at a mean distance of 50.61; but the periods of the comets are very far from certain. Comet 1862 III (related to the Perseid meteors) is supposed to have a period of one hundred and twenty-one years; while there has been stated an identity between the comets of 1532 and 1661. In 1911 it was pointed out that there was a distinct similarity between the Kiess and Quénisset comets of that year and comets 1790 I and III, respectively. If this could have been established, there would have been much stronger evidence for the hypothetical planet; but in each case the differences were such as to lead to the conclusion that the similarity was merely fortuitous. It is necessary, therefore, to search for comets whose periods can be irrefragably shown to be in the neighborhood of one hundred and twenty-one years, i. e., they must be seen at two apparitions at least.

There have been one or two other investigations concerning unknown planets. Pickering[7] stated in 1910 that the orbits of comets and a certain perturbation of Neptune could be explained by the existence of a large and very distant dark body in a direction perpendicular to the ecliptic. Another interesting suggestion is that of Prof. Forbes[8], who gives some evidence for supposing that the comet of 1556 was split into three in aphelion, about the year 1702, by an ultra-Neptunian planet at the great distance of eighty-seven units.

The conclusion reached in this paper is, therefore, that the orbits of comets present the most hopeful method of arriving at the unknown planet, their results agreeing roughly, as to the mean distance, with those derived from the perturbations of Uranus. The "capture" theory is, however, only rough; and for a proper treatment it will be necessary to discuss in general the motion of a comet under the combined attraction of the sun and a planet. These "parabolic orbits," as they may be called (since, for a small disturbing mass, they are approximately parabolas), present enormous mathematical difficulties, even compared with the case of orbits nearly circular. In the lunar theory, a revolution was effected by the suggestion of G. W. Hill, to treat the question as a particular case of the problem of three bodies and to solve by series. The parabolic case is complicated by the nonconvergence of any proposed series, and practically nothing has been done in the way of mathematical analysis. Nevertheless, it seems to be a necessary step in the establishment of the existence of the unknown planet.

[1] See *Nature*, June 17th and August 26th, 1909.

[2] *Comptes Rendus*, March, 1909. See *Nature*, July 8th, 1909.

[3] "Encyclopaedia Britannica," 11th edition, Art. "Comet."

[4] *Royal Astronomical Society, Monthly Notices*, LXX, 5 (March, 1910).

[5] "The Motion of the Solar System relatively to the Interstellar Absorbing Medium," *Monthly Notices, Roy. Astr. Soc.* LXXII. (1912, Suppl. No.)

[6] See *Nature*, October, 1902.

[7] See *Science Abstracts*, February 25th, 1911.

[8] *Monthly Notices, Roy. Astr. Soc.*, December, 1908.

Correspondence

[*The editors are not responsible for statements made in the correspondence column. Anonymous communications cannot be considered, but the names of correspondents will be withheld when so desired.*]

The Control of the Mississippi Floods

[*Most of the objections raised by Mr. Lahroy Slusher in the letter here published will be found answered in Mr. Charles D. Townsend's excellent articles on the "Control of the Mississippi Flood" (p. 6 and 279 of* Supplement) *and in our editorial which appeared in the* Scientific American *of May 24th.*—Editor.]

To the Editor of the Scientific American Supplement:

As one who has had some experience in irrigation in the arid west and drainage in the upper and lower States of the Mississippi Valley, I take this occasion to express my utter disapproval of Mr. Charles W. Baker's contribution, appearing in the May 3rd issue of the Scientific American, entitled "Floods and the Problem of River Regulation."

In going over Mr. Baker's article, I note he endeavors especially to establish the following conclusions, with which I take issue:

First. He would ask you to believe it was a fallacy to presume that deforestation of mountainous regions and drainage of the lowlands and swamps at the head waters of a stream have any bearing on the flood stages of the river below.

Second. That there are not reservoir sites enough at the head waters of the Mississippi River and its tributaries to materially affect the flood flow at Cairo, Ill.

Third. That reservoirs as a means of impounding flood waters would be far too expensive for the benefits derived.

Fourth. That inasmuch as disastrous floods seldom occur twice in the same part of the country, it would be impracticable to construct reservoirs to control these floods.

Fifth. That a "levee only" system is the only hope of controlling the destructive floods of the Mississippi River and that the control of these floods i a local affair, at most a matter of State expense and concern.

Referring to the first exception, deforestation and artificial drainage at head waters: Forests undoubtedly moderate stream flow, first by absorption and secondly by materially retarding the run-off. While operating in the inter-mountain region of the west, the writer had ample occasion to study this matter for himself as well as to discuss it with numerous members of the United States Forestry Service, including Mr. Gifford Pinchot, then superintendent of the National Forest Service. Without exception these gentlemen, as well as many prominent engineers in the west, were unanimous in their belief that wooded lands, either in the mountains or plains country, would materially slacken the otherwise rapid run-off from a given watershed.

As to the drainage of lowlands and swamps in the upper regions of a watershed having no direct effect on the stream flow below, I think this will at once be apparent as an erroneous conclusion by every engineer and layman reader in the country who has had any experience in the drainage of either. In short, anybody knows that the tens of thousands of ponds and wet marsh areas (nothing more than small reservoirs) which have been drained during the last ten years in the northern States by means of artificial canals, have hastened the waters into these hundreds and thousands of streams throughout every one of the States forming the upper drainage basin of the Mississippi, Ohio and Missouri Rivers above Cairo. Not only have these lakes, ponds and marsh lands been drained and turned into fertile farms by means of large artificial canals, but the waters from tens of millions of other acres have been systematically gathered by means of tile ditches, thus again greatly hastening the run-off. Indeed, even great creeks and rivers have oft-times undergone a similar drainage process of cleaning out, deepening and straightening, all with a view of quickening local drainage and hurrying the waters down their course to the sea. Now, if anyone doubts this statement, just go and ask some of the municipalities and farming communities which have expended some of the millions of dollars which have paid for this drainage; just ask them to tell you how much faster their big floods run down stream now, as against olden days, before artificial assistance was given nature.

Then, certainly, if the rainfall of the great agricultural regions is run down stream in a third or a fourth of the time previously required, some one below is bound to feel the effect. This is as natural as it is to suppose that water will run down stream. And when it gets down below and meets the waters of ten thousand other streams, which have been similarly "hastened," well, you are going to greatly aggravate the flood condition below, of course. This is just exactly what has been going on in every State of the Mississippi drainage basin during the past twenty years, which largely contributed to the terrible flood plane recently attained at Cairo, Ill., and the river below.

Secondly, Mr. Baker feels sure there are no reservoir sites available at th head waters of the rivers. Even if there were, he tells you that the land is too valuable.

Let us see as to the reservoir sites, beginning, say, on the Ohio River, and its tributaries. In looking over

the government contour map we find the Ohio drainage basin contains approximately 201,000 square miles, all of which drain into the Ohio River above Cairo, Ill. More than half of this area is found to be hilly or mountainous. However, let us begin, for argument's sake, by excluding that part of the country which drains into the Ohio River from the States of Indiana, Illinois and Ohio, three agricultural States, where it is admitted reservoir sites would be not only difficult to find and construct, but the ground inundated would be valuable agricultural property. Exclusive of these three States there still remains more than half of the entire Ohio drainage basin with its thousands of streams in the western portion of Pennsylvania, New York, West Virginia, Kentucky, Tennessee and Alabama, the waters of which contribute considerably more than half the total flow which passes down the Ohio River at Cairo. In the last named States are found such great streams as the Mononghela, Allegheny, Cumberland, Tennessee, Kentucky and hundreds of smaller streams, which pass through the hills and mountains and afford innumerable reservoir sites for impounding flood waters. In practically all cases the land inundated would be owned largely by the United States Government, or of little value agriculturally.

Third. Reservoirs as a means of lowering the flood plane at Cairo are not too expensive, when considering the benefits to be derived from a single ten-year period. Having personally had experience in the construction of reservoirs in the arid west, where the Government and private corporations have found it possible to store the entire flood flow of many streams, both great and small, I feel no hesitancy in saying that the benefits derived during any period of ten years would more than offset the total cost of construction. Here I would also call attention to the report of the Pittsburgh Flood Commission, appointed from the membership of the Pittsburgh Chamber of Commerce, who were desirous of ascertaining the practicability of reservoir sites on the three great streams above Pittsburgh and forming the Ohio River just below the city. This commission investigated the matter for more than two years. Their engineers made surveys of dozens of reservoir sites and computed the cost of constructing them, with a view of intelligently advising the Pittsburgh Chamber of Commerce whether or not it were possible to store enough water in the mountainous country which the three rivers passed, to materially lessen the flood stage at Pittsburgh. After spending upward of $125,000 in these investigations, which included studies throughout America and foreign lands, the committee made a distinctly favorable report, recommending the construction of some seventeen reservoirs in the State of Pennsylvania. These seventeen reservoirs, said the committee, could be constructed at a cost of approximately $60,000,000 and would reduce the flood plane at Pittsburgh from 15 to 18 feet. In other words, the cost of these reservoirs would be more than paid every ten years by the saving to the city of Pittsburgh alone. And this, mind you, taking no account of the electrical power possibilities to be derived from the various reservoirs thus created and other benefits obtainable from the extra flow of the streams below, not the least of which is river navigation between Pittsburgh and Cincinnati during the low stages of the river in the summer months.

The above report, together with innumerable other investigations and favorable findings by competent engineers, would indicate that without reasonable question enough reservoir sites are available and could be economically constructed on the head waters of the hundreds of streams forming the Ohio drainage basin in the States of Pennsylvania, New York, West Virginia, Kentucky, Tennessee and Alabama, and that by the construction of these reservoirs the crest of the flood at Cairo could be reduced from 10 to 20 feet.

The same thing can be said of the Missouri River and its head waters, which largely originate in the mountainous States of Colorado, Wyoming, Montana, Alberta, Canada, and North and South Dakota, except that in addition to the water power possibilities in the west, the same water can be used for the irrigation of millions of acres of dry lands, now worthless without water to germinate plant life upon them.

But aside from the above reservoir possibilities in the Ohio and Missouri River basins, it must also be remembered that there are many great streams entering the Mississippi River from the west below Cairo, Ill.; more particularly, the Arkansas, the White, the Black and Red Rivers. Many of these streams originate in the mountains of Colorado, New Mexico or in the hills of Texas and pass through the mountainous regions of Missouri and Arkansas where numerous practical reservoir sites may be found. The waters from these rivers, it should be borne in mind, have a very great deal to do with the disastrous floods in the lower Mississippi Valley. In fact, it often happens that their flood discharge is made in the Mississippi River simultaneous with a great flood stage at Cairo or Memphis, thus straining to the utmost the levee system on which the lower country must depend in conveying these floods to the sea. This was the case in both the great floods of 1912 and 1913.

Fourth. Mr. Baker would also have you believe that floods seldom occur in the same region; therefore, it would be useless to construct reservoirs to control them. But reference to the governmental rainfall charts of our great floods during the last half century will indicate that the waters which fell in the hilly and intermountain portions of the drainage basin of the Mississippi and its tributaries have played a very important part in each and every flood, at and below Cairo, Ill. To be more explicit, Mr. Baker in his article of May 3rd, makes no mention whatever of the great rainfall which occurred in Pennsylvania, West Virginia, Kentucky, Tennessee and Alabama. He would have you believe it was the Dayton and Columbus, Ohio, and Indiana floods alone which did the havoc at Cairo and the Mississippi River below. This is erroneous, since the Government bulletins clearly indicate that disastrous floods were experienced on the head waters of the Cumberland, Tennessee and Kentucky Rivers, also the Allegheny and the Mononghela Rivers and that a 9-inch rain was also experienced at Little Rock, Ark., in the drainage basin of the Arkansas River. Each and every one of these rains had its full pro rata share of the responsibility for the second disastrous flood in the year 1913.

It is the last straw that breaks the camel's back. Just so it is with the waters from the streams collectively forming the Mississippi River drainage basin. Therefore, it is apparent that were reservoirs to be constructed upon the streams passing through the mountainous country, where reservoir sites are plentiful and their construction feasible, the waters of these streams could be stored during the time of great floods and taken out after the streams originating in the plains country were restored to their normal flow.

This is just what the Newlands River Regulation bill proposes that the United States Government shall do, plus the utilization of the best possible levee system or the Mississippi River from Cairo to the Gulf, which Uncle Sam can build—not in the slightest an abandonment of the present levee system, as the enemies of this bill would have you believe.

Fifth. Answering the statement that levees are the only hope of controlling the destructive Mississippi Valley floods, I need only here refer to the record of disaster which has been made during the past two years in connection with the three great floods which were sent down upon us in the lower Mississippi Valley by our twenty-four northern sister States.

On each occasion we have been visited by the levee engineers and experts, by the engineers and members of the Mississippi River Commission, including the president of that august body, Mr. C. McD. Townsend, who have alike assured us of the most excellent condition of our levees and of their ability to withstand every demand made of them. But scarcely have these words been cast into type and spread broadcast among our people, than came the news of a disastrous crevasse here and there, at just such points, bear in mind, as were most unlooked for by these expert theoretical engineering gentlemen, whose principal business it seems to have been to pacify an uneasy people, whose property lay behind these levees.

Whatever else the past three floods have proven, they have demonstrated conclusively that levees alone will not stand the strain. It matters not how high, how wide or how strong or by whom the levees are built, they have proven to be inadequate. Sole dependency on the levees is not logical. The higher, wider and stronger levees are built and the higher the water level in the Mississippi River is allowed to rise, the greater will be the danger of crevasses, not necessarily through the breaking of the levees, but by what is commonly known as "blow outs" which means complete annihilation. These so-called "blow outs" usually occur at points least expected. They are not due to the height of the levee, lack of width or imperfect construction, but are caused more generally by sub-strata of quicksand or other faulty soil strata far beneath the levees. When the water pressure from the river side reaches a certain stage, these strata are going to yield to this pressure, just as certain as water will yield to gravity. And for this reason it is practically the unanimous judgment of the well-informed in this country that not only do we need the levees and reservoirs at the head waters of the Mississippi River and its tributaries, but we need numerous and ample spillways to help reduce the height of the water plane in the river, so that our levees wil never be called upon to take care of more than a fixed amount of water.

All these features are embodied in the Newlands River Regulation bill.

That the control of the great Mississippi River floods is a local affair is altogether a ridiculous statement and I express both surprise and regret that Mr. Baker would advance such a theory. Upon the same basis, why should not the interior States of the Union refuse to submit to our vast annual naval expenditures, upon the very good ground that they had no coastline to defend and consequently should not be taxed to maintain our ever increasing ironclad fleet.

Any great calamity or act of destruction which affects an American community, affects in proportion to the size and nature of that calamity, the whole nation. The great destructive floods which have been sweeping the Mississippi Valley during the past two years and at alarmingly increasing intervals during the past fifty years, is nothing less than a great national disaster, impoverishing millions of the nation's citizens, reducing correspondingly the national wealth and taxable property.

That Federal control of the Mississippi River is an absolute necessity and that it is a long neglected duty, is no more a matter of question. The Newlands River Regulation bill, now pending before the United States Senate, is the vehicle on which we should ride to Washington and knock at the doors of Congress for immediate relief.

J. Lahroy Slusher.

New Orleans, La.

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